HUMAN

PHYSIOLOGY;

ILLUSTRATED BY ENGRAVINGS.

BY

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"Vastissimi studii primas quasi lineas circumscripsi."—HALLER.

SECOND EDITION,

WITH NUMEROUS ADDITIONS AND MODIFICATIONS.

IN TWO VOLUMES.

VOL. I.

PHILADELPHIA:

CAREY, LEA & BLANCHARD.

1836.

TO

JAMES MADISON,

EX-PRESIDENT OF THE UNITED STATES, &c. &c.

Alike distinguished as an illustrious benefactor of his country; a zealous promoter of science and literature, and the friend of mankind—this work, intended to illustrate the functions executed by that being, whose moral and political condition has been with him an object of ardent and successful study, is, with his permission, inscribed, in testimony of unfeigned respect for his talents and philanthropy, and of gratitude for numerous evidences of friendship, by his obedient and obliged servant,

THE AUTHOR.

PREFACE TO THE SECOND EDITION.

The flattering reception, which this work has met with from the profession, demands the grateful acknowledgments of the Author, and his utmost zeal to render the work still more worthy of favour. He has, accordingly, endeavoured to add to this edition whatever of importance has been published since the appearance of the first edition in this country, and in the different countries of Europe, on the various topics which the work embraces; to deduce correct inferences from them, and to make such alterations and improvements as suggested themselves on revision. That these have not been to a trifling extent may be appreciated by a comparison of this with the former edition.

For the favourable notices, which have been taken of the work in the different periodicals, the Author is sincerely thankful. He has, on many occasions, profited greatly by their strictures and suggestions.

The Author cannot conclude this brief preface without congratulating the profession, and the community in general, that the venerable patriot, to whom he had the honour to dedicate the first edition, is still preserved to his country; and it is with no little gratification, that he embraces another opportunity for expressing those sentiments, which he so warmly entertains for that distinguished individual.

Baltimore, Dec. 1, 1835.

PREFACE TO THE FIRST EDITION.

The present work was undertaken chiefly for the purpose of forming a text-book for the author's students in the University of Virginia, in which a full course of lectures on Physiology is made to precede the investigation of Pathology, or "diseased Physiology," as it has been, not inappropriately, termed.

Of late, the study of Physiology has become much more common both with the professional and unprofessional inquirer. The necessity for studying man physically, as well as morally, has been strongly inculcated by some of the best writers on morals and legislation; and, in France, M. Bourdon has compiled a series of dialogues for the young female student,—such topics being suppressed, as were regarded by him to be unsuitable, but enough being retained to preclude their admission into the library of the American lady.

In preparing the present work, the author has availed himself freely of the labours of his predecessors. His object has been to offer a view of the existing state of the science rather than to strike out into new, and perhaps devious, paths. To the labours of Adelon and Chaussier,—especially of the former,—of Blumenbach, Richerand, Magendie, Rudolphi, Broussais, Sir Charles Bell and others, who have had the chief agency in raising Physiology to its present elevated condition, he has been indebted for essential aid; and many of the illustrations have been taken from the admirable graphic delineations of the last mentioned distinguished physiologist. Some of these sketches, owing to the distance of the author from the press, are not so uniform in regard to size, or so unexceptionable in certain other respects, as is desirable; but their general execution reflects credit upon Mr. Drayton, under whose superintendence they were engraved.

The author has to regret his not having seen a copy of the "Principles of Medicine," recently published by Dr. Samuel Jackson; especially as he is satisfied, from the reputation of the author, as well as from a notice of the work in the nineteenth number of *The American Journal of the Medical Sciences*, from the pen of an able professor in the University of Maryland, that he would have met with many valuable remarks and suggestions. He has likewise to regret that the useful notes, appended to the third American edition of the translation of Broussais' *Physiology applied to Pathology*, by Drs. Bell and La Roche,—did not reach him in time to be available.

CONTENTS OF VOL. I.

CLASS II.

HUMAN PHYSIOLOGY.

PRELIMINARY OBSERVATIONS.

OF NATURAL BODIES.

The extensive domain of Nature is divisible into three great classes:—*Minerals, Vegetables, and Animals.* This division was universally adopted by the ancients, and still prevails, especially amongst the unscientific. When, however, we carefully examine their characteristics, we discover, that the animal and the vegetable resemble each other in many essential particulars. This resemblance has given occasion to the partition of all bodies into two classes:—the *Inorganic*, or those not possessing *organs* or instruments adapted for the performance of particular actions or functions, and the *Organized*, or such as do possess this arrangement.

In all ages, philosophers have attempted to point out, as the poet Milton expresses it, a

> "Vast chain of being, which from God began,
> Natures ethereal, human, angel, man,
> Beast, bird, fish, insect, what no eye can see,
> No glass can reach—"

the links of which chain they have considered to be constituted of all natural bodies; passing by insensible gradations through the inorganic and the organized, and forming a rigid and unbroken series. Crystallization has been esteemed by them as the highest link of the inorganic kingdom; the lichen, which encrusts the stone, as but one link higher than the stone itself; the mushroom and the coral, as the connecting links between the vegetable and the animal; and the immense space, which separates man—the highest of the mammalia—from his Maker, they have conceived to be occupied, in succession, by beings of gradually increasing intelligence.

If, however, we investigate the matter minutely, we discover that many links of the chain appear widely separated from each other; and that, in the existing state of our knowledge, the catenation cannot be esteemed rigidly maintained.

Let us inquire into the great characteristics of the different kingdoms, and endeavour to describe the chief points in which living bodies differ from those that have never possessed vitality, and into the distinctions between organized bodies themselves.

Difference between Inorganic and Organized Bodies.

Inorganic bodies possess the common properties of matter. Their elements are fixed and uncontrolled under ordinary circumstances. Their study constitutes *Physics*, in its enlarged sense, or *Natural Science*. Organized bodies have properties in common with the inorganic, but they have likewise others superadded, which control the first in a singular manner. They are beings, whose elements are undergoing constant mutation, and the sciences treating of their structure and functions are *Anatomy* and *Physiology*.

1. *Origin.*—They differ, in the first place, from each other, in their origin. Inorganic bodies are not born; they do not arise from a parent; they spring from the general forces of matter, the particles being merely in a state of aggregation, and their motions are regulated by certain fixed and invariable laws. The animal and the vegetable, on the other hand, are the products of generation; they must spring from a being similar to themselves, and they possess the principle of life, which controls the ordinary forces of matter. Yet it has been supposed that they are capable of creating life; in other words, that a particular organization presupposes life.

This is not the place for entering into the question of generation. It will be sufficient at present to remark, that in the upper classes of animals, the necessity of a parent cannot be contested; the only difficulty, that can possibly arise, regards the very lowest classes, and analogy has appeared, in their case, to warrant the conclusion, that every living being must spring from an egg or a seed.

2. *Shape.*—Again; the *shape* of inorganic bodies is not fixed in any determinate manner. It is true, that by proper management, every mineral can be reduced to a primitive nucleus, which is the same in all minerals of like composition; still the shape of the mineral, as it presents itself to us, differs. Carbonate of lime, for example, although it may always be reduced to the same primitive nucleus, assumes various appearances; sometimes being rhomboidal; at others, in regular hexaëdral prisms; in solids, terminated by twelve scalene triangles, or in dodecaëdrons, whose surfaces are pentagons.

In organized bodies, on the contrary, the shape is constant. Each animal and vegetable has the one that characterizes its species, so that no possible mistake can be indulged; and this applies not only to the whole body, but to every one of its parts, numerous as they are.

3. *Size.*—The size of an inorganic body is by no means fixed. It may be great, or small, according to the quantity present of the particles, that have to form it. A crystal, for example, may be minute or the contrary, according to the number of saline particles in the solution; whilst organized bodies attain a certain size,—at times by a slow, at others by a more rapid growth,—but in all cases the due proportion is preserved between the various parts, between

the stem and the root, the limb and the trunk. Each vegetable and each animal has its own size, by which it is known; and although we occasionally meet with dwarf or gigantic varieties, these are infrequent, and mere exceptions confirming the position.

4. *Chemical character.*—Great difference exists between inorganic and organized bodies in this respect.

In the mineral kingdom are found all the elementary substances, or those which chemistry, at present, considers *simple*, amounting to upwards of fifty, and comprising oxygen, hydrogen, boron, carbon, phosphorus, sulphur, selenium, iodine, fluorine, chlorine, bromine, azote, silicium, zirconium, thorinium, aluminium, yttrium, glucinium, magnesium, calcium, strontium, barium, sodium, potassium, lithium, manganese, zinc, iron, tin, arsenic, molybdena, tungsten, columbium, chromium, antimony, uranium, cerium, cobalt, titanium, bismuth, cadmium, copper, tellurium, lead, mercury, nickel, osmium, rhodium, silver, gold, platinum, palladium, and iridium. In the organized, a few only of these elements of matter are met with, viz. oxygen, hydrogen, azote, carbon, sulphur, phosphorus, &c.

In the inorganic body, the composition is more simple; several consist of but one element; and, when composed of more, the combination is rarely higher than ternary. The organized body, on the other hand, is never simple nor even binary. It is always at least ternary or quaternary. The simplest vegetable consists of a union of oxygen, carbon, and hydrogen; the simplest animal, of oxygen, hydrogen, carbon, and azote.

The composition of the mineral again is constant. Its elements have entirely satisfied their affinities, and all remains at rest. In the organized kingdom, however, the affinities are not satisfied; compounds are formed to be again decomposed, and this happens from the earliest period of fœtal formation till the cessation of life: all is in commotion, and the chemical character of the corporeal fabric is incessantly undergoing modification.

In chemical nomenclature, the term *element* has a different acceptation, according as it is applied to inorganic or organic chemistry. In the former, it means a substance, which, in the present state of the science, does not admit of decomposition. We say, in the present state of the science, for many of the bodies, now esteemed compound, were not many years ago classed amongst the simple or elementary. It is not more than twenty-eight years since the alkalies were found to be composed of two elements. Previously, they were considered simple. In the animal and the vegetable, we find substances, also called *elements*, but with the epithet *organic*, because only found in *organized* or living bodies, and therefore the exclusive products of organization and life. For example, in both animals and vegetables we meet with oxygen, hydrogen, carbon, azote, and different metallic substances: these are *chemical* or *inorganic elements*, and we further meet with albumen, gelatine, fibrine, osmazome, &c. substances, which constitute the various organs, and which, therefore, have been termed *organic elements* or *compounds of organization;* yet they are capable of decomposition, and in one sense, therefore, not elementary.

In the inorganic body, all the elements, that constitute it, are formed by the agency of general chemical affinities; but, in the organized, the formation is produced by the force, that presides over the formation of the organic elements themselves—the force of life. Hence the cause why the chemist is able to decompose and restore many of the inorganic bodies, whilst the products of organization and of life set his art at defiance.

The different parts of an inorganic body enjoy an existence independent of each other; whilst those of the organized are materially dependent. No part can, indeed, be injured without the mass and the separated portion being more or less affected.

If we take a piece of marble, which is composed of carbonic acid and of lime, and break it into a thousand fragments, each portion will be found to consist of carbonic acid and of lime. The mass will be destroyed, but no piece will suffer from the disjunction. They will continue as fixed and unmodified as at first. Not so with an organized body. If we break the branch from a tree, the stem itself participates more or less in the injury; the detached branch speedily undergoes striking changes; it withers; becomes shrivelled, and, in the case of the succulent vegetable, undergoes decomposition; a portion of its constituents, no longer held in control by the vital agency, enters into new combinations, is given off in the form of gas, and the remainder sinks to earth.

Changes, no less impressive, occur in the animal when a limb is separated from the body. The parent trunk suffers; the system recoils at the first infliction of the injury, but subsequently arouses itself to a reparatory effort,—at times with such energy as to destroy its own vitality. The separated limb, like the branch, is given up, uncontrolled, to new affinities; and putrefaction soon reduces the mass to a state in which its previously admirable organization is no longer perceptible.

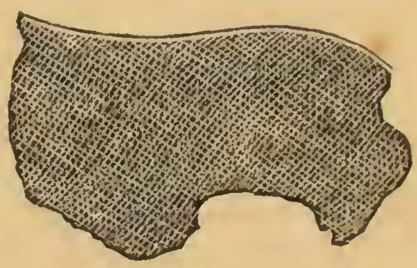
Some of the lower classes of animals may indeed be divided with impunity, and with no other effect than that of multiplying the animal in proportion to the number of sections, but these are exceptions; and we may consider the destructive process,—established when parts of organized bodies are separated,—as one of the best media of distinction between the inorganic and organized classes.

5. *Texture.*—In this respect the inorganic and organized differ considerably,—a difference which has given rise to their respective appellations. To one of these only can the term *texture* be with propriety applied.

If we examine a vegetable or animal substance with attention, we shall find, that it has a regular and determinate arrangement or structure; and we readily discover, that it consists of various parts; —in the vegetable, of wood, bark, leaves, roots, flowers, &c.; and in the animal, of muscles, nerves, vessels, &c.; all of which appear to be instruments or *organs* for specific purposes in the economy of the being. Hence the body is said to be *organized*, and the result, as well as the process, is called *organization*.

The particles of matter in an organized body, so far as we can detect them, constitute fibres, which interlace and intersect each other in all directions, and form a spongy areolar texture or tissue. (Fig. 1.) Of these tissues the various organs of the body are composed. In the inorganic substance, the mass is homogeneous; the smallest particle of marble, as we have seen, consists of carbonic acid and lime; and all the particles concur alike in the formation and preservation of the body.

Fig. 1.



Lastly, whilst an inorganic body, of a determinate species, has always a fixed composition, the living being, although constituting a particular species, may present individual differences, giving rise, in the animal, to various *temperaments*, *constitutions*, &c.

6. *Mode of preservation.*—Preservation of the species is, in the animal, the effect of reproduction. As regards individual preservation, that of the mineral is dependent upon the same actions that effected its formation,—on the persistence of the affinities of cohesion and combination, which united its various particles. The animal and the vegetable, on the other hand, are maintained by a mechanism peculiar to them. From the bodies surrounding them, they lay hold of nutritious matter, which, by a process of elaboration, they assimilate to their own composition; at the same time, they are constantly absorbing or taking up particles of their own structure, and throwing them out. The actions of composition and decomposition are constant whilst life exists, although subject to particular modifications at different periods of existence, and under different circumstances. This process is called *nutrition*.

The inorganic and organized are alike subject to changes during their existence; but the character of these changes, in the two classes, differs essentially.

The mineral retains its form, unless acted upon by some mechanical or chemical force. Within, all the particles are at rest, and no internal force exists which can subject them to modification. There is no succession of conditions which can be termed *ages*. How different is the case with organized bodies! Internally, there is no rest; from birth to death all is in a state of activity. The plant and the animal are subject to incessant changes. Each runs through a succession of conditions or *ages*. We see it successively develope its structure and functions, attain maturity, and finally decay.

Characteristic differences exist in the nature of the exterior of the two divisions, as well as in their mode of increase. Inorganic bodies have no covering to defend them, no exterior envelope to preserve their form. A stone is the same at its centre as at its circumference, whilst organized bodies are protected by an elastic and extensible covering, differing from the parts beneath, and inservient to valuable purposes in the organized economy.

Every change, to which an inorganic body is liable, must occur at its surface. It is there that the particles are added or abstracted when it experiences increase or diminution of size. This increase—for *growth* it can scarcely be termed—takes place by *accretion* or *juxtaposition*, that is, by the successive application of fresh particles upon those that form the primitive nucleus; and diminution in bulk is produced by the removal of the external layers or particles. In organized substances, increase or growth is caused by particles deposited internally, and diminution by particles subtracted from within. We see them, likewise, under two conditions, to which there is nothing similar in the mineral kingdom,—*health*, and *disease*. In the former, the functions are executed with freedom and energy; in the latter, with oppression and restraint.

7. *Termination.*—Every body, inorganic or organized, may cease to exist, but the mode of cessation varies greatly in the two great divisions of natural bodies.

The mineral is broken down by mechanical violence, or it ceases to exist, in consequence of modifications in the affinities, which held it concrete. It has no fixed duration, but its existence may be terminated at any moment, when the circumstances, that retained it in aggregation, are destroyed.

The vegetable and the animal, on the other hand, can carry on their functions for a period only, which is fixed and determinate for each species. For a time, new particles are deposited internally. Its bulk is augmented, and its external envelope distended, until maturity or full developement is attained; but, after this, decay commences; the functions are exerted with gradually diminishing energy; the fluids decrease in quantity; and the solids become more rigid,—circumstances premonitory of the total cessation of vitality. This term of duration is very different in different species. Whilst many of the lower classes of animals and vegetables have but an ephemeral existence, some of the more elevated individuals of the two kingdoms outlive a century.

8. *Motive forces.*—Lastly, observation has satisfactorily proved, that there are certain forces which affect matter in general, the inorganic as well as the organized, but that, in addition to these, the organized possess a peculiar force or forces, which modify them in the most remarkable manner. Hence, we have *general forces*, and *special* or *vital;* the first acting upon all matter, the dead and the living, and including the forces of *gravitation*, *cohesion*, *chemical affinity*, &c.; the latter being exclusive to living beings.

Such are the chief distinctions to be drawn between the two great divisions of natural bodies, the inorganic and the organized.

By the comparison which has been instituted, the great objects of physiology, the phenomena of life, have been indicated. To inquire into the mode in which a living being is *born*, *nourished*, *reproduced*, and *dies*, is the legitimate object of this science.

We have, however, entered into a comparison only of the inorganic with the organized. The two divisions constituting this latter class differ also materially from each other. Into these differences we shall now inquire.

Difference between Animals and Vegetables.

The distinctions between these divisions of organized bodies are not so rigidly fixed, or so readily appreciated, as those we have considered.

There are certain functions possessed by each, and hence called *vegetative*, *plastic*, or *organic*—nutrition and reproduction for example. But vegetables are endowed with these only. All organized bodies must necessarily have the power of assimilating foreign matters to their own substance, and of producing a living being similar to themselves, otherwise all species, having a limited duration, would perish.

In addition to these common functions, animals have two others, *sensation* and *voluntary* motion, by the possession of which they are said to be *animated*. Hence they are termed *animals*, and the condition is called *animality*. This division of the functions into *animal* and *organic* has been adopted, with more or less modification, by the generality of physiologists.

Between animals and vegetables, that are situated high in their respective classes, no error can possibly be indulged. The characters are obvious at sight. No one can confound the horse and the oak, the butterfly and the potatoe. It is on the lower confines of the two kingdoms that we are liable to be deceived. Many of the zoophytes have alternately been considered vegetable and animal; and it is not until of modern date, that the sponge has been universally elevated to that kingdom to which it is entitled. Nor is this to be wondered at. In its attachment to the rock, it is as immovable as the lichen is to the slate, and almost equally deficient in the usual characteristics of animality. In general, however, we are able to classify any doubtful substance with accuracy, and the following are the principal points of difference.

1. *Composition.*—The essential elements of organized matter are, carbon, oxygen, hydrogen and azote, with alkaline and earthy salts, variously combined. Vegetables consist of the three first of these elements, carbon, oxygen, and hydrogen. Azote is possessed in addition by the animal; yet there are many animal substances, as we shall see, that contain no azote. Plants have scarcely any; and generally, when it is met with, it will be found in some part,—scarcely ever distributed through the whole. In the fungi, traces of

a vegeto-animal matter have been detected by the chemist, but they have only been traces. In consequence of this difference of composition, animal substances are easily known from vegetable by burning;—a fact, which, as Dr. FLEMING has remarked, is interesting to the young naturalist, when he may be uncertain to which kingdom to refer any substance met with in his researches. The smell of a burnt sponge, of coral, or other zoophytic animal, is so peculiar, that it can scarcely be mistaken for that of a vegetable body in combustion.

2. *Texture.*—In this respect, important differences are observable. Both animals and vegetables consist of solid and fluid parts. In the former however, the fluids bear a large proportion; in the latter the solids. This is the cause why decomposition occurs so much more rapidly in the animal than in the vegetable, and in the succulent than in the dry vegetable.

If we analyze the structure of the vegetable, we cannot succeed in detecting more than one elementary tissue, which is *vesicular*, or arranged in areolæ or vesicles, and appears to form every organ of the body, whilst in the animal, we discover at least three of these anatomical elements, the *cellular*—analogous to that of the vegetable—the *muscular*, and the *nervous*.

The vegetable has no great splanchnic cavities containing the chief organs of the body. It has a smaller number of organs, and none that are destined for sensation or volition; in other words, no brain, no nerves, no muscular system; whilst the organs, of which it consists, are simple and readily convertible into each other. This is not the case with the animal.

But these differences in organization, striking as they may appear, are not sufficient for rigid discrimination, as they are applicable only to the upper classes of each kingdom. In many vegetables, the fluids appear to preponderate over the solids. Numerous animals are devoid of muscular and nervous tissues, of splanchnic cavities, and apparently of vessels, and distinct organs; whilst Messrs. Dutrochet, Brachet, and others, admit the existence of a rudimental nervous system, even in vegetables.

3. *Sensation and voluntary motion.*—One manifest distinction exists between animals and vegetables. Whilst the latter receive their nutrition from the objects situated around them—irresistibly and without volition, or the participation of mind—and whilst the function of reproduction is effected without the union of the sexes; volition and sensation are both necessary for the nutrition of the former, and for the acts requisite for the reproduction of the species. Hence, the necessity of two faculties or functions in the animal, which are wanting in the vegetable, viz. *sensibility*, or the faculty of consciousness and feeling; and *motility*, or the power of moving the whole body or any of its parts at the will of the being. Vegetables are possessed of *spontaneous*, but not of *voluntary* motion. Of the former we have numerous examples in the direction of the

branches and upper surfaces of the leaves, although repeatedly disturbed, to the light; and in the unfolding and closing of flowers, at stated periods of the day. This, however, is quite distinct from the sensibility and motility that characterize the animal. By sensibility he feels his own existence,—becomes acquainted with the universe, —appreciates the bodies that compose it, and experiences all the desires and inward feelings that solicit him to the performance of those external actions, which are requisite for his preservation, as an individual and as a species. By motility he executes those external actions, which his sensibility may suggest to be necessary.

By some naturalists it has been maintained, that those plants, which are borne about on the waves, and fructify in that situation, exhibit to us examples of the locomotility, which is described as characteristic of the animal. One of the most interesting novelties, in the monotonous occurrences of a voyage across the Atlantic towards the Gulf of Florida, is the almost interminable quantity of the *Fucus natans*, *Florida weed*, or *Gulph weed*, with which the surface of the ocean is covered. But how different is this motion from the locomotility of animals! It is a subtlety to conceive them identical. The weed is passively and unconsciously borne whithersoever the winds and the waves may urge it, whilst locomotion requires the direct agency of volition, of a nervous system that can excite, and of muscles that can act under such excitement.

The *spontaneity* and *perceptivity* of plants, as they have been termed, must also be explained in a different manner from the elevated function of sensibility on which we shall have to dwell. These properties must be referred to the fact of certain vegetables being possessed of the faculty of contracting on the application of a stimulus, independently of sensation or consciousness.

If we touch the leaf of the sensitive plant, *Mimosa pudica*, the various leaflets collapse in rapid succession. In the barberry bush, *Berberis vulgaris*, we have another example of the possession of this faculty. In the flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament, near the bottom. The susceptibility of this part is such, that the filament immediately contracts, and strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this result, provided no concussion be given to the whole. After awhile, the filament retires gradually, and may be again stimulated, and when each petal, with its annexed filament, has fallen to the ground, the latter, on being touched, shows as much sensibility as ever.

These singular effects are produced by the power of *contractility* or *irritability*, the nature of which will fall under consideration hereafter. It is possessed equally by animals and vegetables, and is essentially organic and vital. This power, we shall see, needs not the intervention of volition: it is constantly exerted in the animal without consciousness, and therefore necessarily without volition. It is exerted in the heart, in the muscular tunic of the intestines,—in every muscle, indeed, of involuntary, as well as of voluntary motion. Its existence in the vegetable does not, consequently, demonstrate that it is possessed of consciousness; and we can hence understand, how certain spontaneous motions may persist without the presence of anything like consciousness or volition.

4. *Nutrition.*—A great difference exists between plants and animals in this respect. The plant, being fixed to the soil, cannot search after food. It must be entirely passive, and obtain its supplies from the materials around, and in contact with it; and the absorbing vessels of nutrition must necessarily open on its exterior. In the animal, on the other hand, the aliment is scarcely ever found in a state fit for absorption: it is crude, and in general requires to be received into a central organ, or *stomach*, for the purpose of undergoing changes, by a process termed *digestion*, which adapts it for the nutrition of the individual. The absorbing vessels of nutrition arise, in this case, from the internal or lining membrane of the alimentary tube. The analogy, however, that exists between these two kinds of absorption is great, and had not escaped the attention of the ancients:—"*Quemadmodum terra arboribus, ita animalibus ventriculus, ventriculus sicut humus*" was an aphoristic expression of universal reception. With similar feelings, Boerhaave asserts, that animals have their *roots* of nutrition in their intestines; and Dr. Alston has fancifully termed a plant an *inverted animal.*

Again, in both plants and animals the residue of the matters absorbed is ejected from the body; but the form and character of the rejected portion vary in the two kingdoms. In the plant, the superfluous quantity is thrown off in gaseous, hydrogenated, or aqueous exhalations: in the animal, the useless portion is *excreted,* or rejected as *excrement*, of which azote is a constituent.

After all, the most essential difference consists in the steps that are preliminary to the reception of food. These, in the animal, are voluntary,—requiring prehension, often locomotion, and always consciousness.

5. *Reproduction.*—In this function we find a striking analogy between animals and vegetables; but differences exist, which must be referred to the same causes, that have produced many of the distinctions already pointed out—the possession, by the animal, of sensibility and locomotility. For example, every part of the generative act is, in the vegetable, without the perception or volition of the being—the union of the sexes, fecundation, and the birth of the new individual are alike automatic. In the animal, on the other hand, the approximation of the sexes is always voluntary, and effected consciously—the birth of the new individual being not only perceived, but somewhat aided by volition. Fecundation alone is involuntary and irresistible.

Again, in the vegetable the sexual organs do not exist at an early period, and are not developed until reproduction is practicable. They are capable of acting for once only, and perish after fecundation; and if the plant be vivacious, they fall off after each reproduction, and are annually renewed. In the animal, on the contrary, they exist from the earliest period of fœtal developement, survive repeated fecundations, and continue during the life of the individual.

Lastly, the possession of sensibility and locomotility lead to other characteristics of animated beings. These functions are incapable of constant, unremitting exertion. *Sleep*, therefore, becomes necessary. The animal is also capable of *expression* or of *language*, in a degree proportionate to the extent of his sensibility, and of his power over the beings that surround him.

But these differences in function are not such striking characteristics as they at first appear. There are many animals, which are as irresistibly attached to the soil as the vegetables themselves. Like the latter, they must, of necessity, be compelled to absorb their food in the state in which it is presented to them. Sensibility and locomotility appear, in the zoophyte, to be no more necessary than in the vegetable. No nervous, no muscular system is required; and, accordingly, none can be traced in them; whilst many of those spontaneous motions of the vegetable, which have been described, have been considered by some to indicate the first rudiments of sensibility and locomotility: and Linnæus has regarded the closure of the flowers towards night as the *sleep*, and the movements of vegetables, for the approximation of the sexual organs, as the *marriage* of plants.

GENERAL PHYSIOLOGY OF MAN.

The observations made on the difference between animals and vegetables have anticipated many topics, which would require consideration under this head. Those general properties which man possesses, along with other animals, have been referred to in a cursory manner. They will now demand a more special investigation.

ON THE MATERIAL COMPOSITION OF MAN.

The detailed study of human organization is the province of the anatomist,—of its intimate composition, that of the chemist. In explaining the functions executed by the various organs, the physiologist will frequently have occasion to trench upon both of these departments.

The *bones*, in the aggregate, form the *skeleton*. The base of this skeleton is a series of *vertebræ*, with the *skull* as a capital—itself regarded as a vertebra by De Blainville. This base is situated on the median line through the whole trunk, and contains a cavity, in which are lodged the brain and spinal marrow. On each side of this, other bones are arranged in pairs, which by some have been called *appendices*. Upon the skeleton are placed *muscles*, for moving the different parts of the body, and for changing its situation with regard to the soil. The body is again divided into *trunk* and *limbs*. The *trunk*, which is the principal portion, is composed of three *splanchnic* cavities, situated one above the other—the *abdomen*, *thorax*, and *head*. These contain the most important organs of the body—those that effect the functions of sensibility, digestion, respiration, circulation, &c. The *head* comprises the *face*, which contains the organs of four of the senses—those of sight, hearing, smell, and taste,—and the cranium, which lodges the brain—the organ of the mental manifestations, and the most elevated part of the nervous system. The *thorax* or *chest* contains the lungs—organs of respiration,—and the heart, the great organ of the circulation. The *abdomen* contains the principal organs of digestion, and, (if we include in it the *pelvis*,) those of the urinary secretion and of generation. Of the *limbs*, the *upper*, suspended on each side of the thorax, are instruments of prehension, and are terminated by the hand, the great organ of touch. The *lower* are situated beneath the trunk, and are agents for supporting the body, and for locomotion. *Vessels*, emanating from the heart, are distributed to every part; conveying to them the blood necessary for their vitality and nutrition: these are the *arteries*. Other vessels communicate with them, and convey the blood back to the heart—the *veins;* whilst a third set communicate also with the arteries, and convey into the circulation, by a particular channel, a fluid called *lymph*—whence they derive the name *lymphatics*. *Nerves*, communicating with the great central masses of the nervous system, are distributed to every part to complete their vitality; and lastly, a membrane or layer, possessed of acute sensibility—the *skin*—serves as an outer envelope to the whole body.

It has been already remarked, that the animal body consists essentially of four ultimate elements—oxygen, hydrogen, carbon, and azote. This is correct as a general principle; but organic chemistry has shown us, that some of the constituents afford little or no traces of azote. It was likewise observed, that two kinds of *elements* enter into the composition of the body—the *chemical* or *inorganic*, and the *organic*, which are *compound*, and formed only under the principle of life.

The *chemical* or *inorganic elements*, met with, are—oxygen, hydrogen, carbon, azote, phosphorus, calcium; and, in smaller quantity, sulphur, iron, manganese, silicium, chlorine; also, sodium, magnesium, &c.

1. *Oxygen.*—This is widely distributed in the solids and fluids, and a constant supply of it from the atmosphere is indispensable to animal life. It is almost always found combined with other bodies, often in the form of carbonic acid—that is, united with carbon. In a separate state it is met with in the air-bag of fishes, in which it is found varying in quantity, according to the species and the depth at which the fish has been caught. Carbonic acid has been detected in an uncombined state in urine, by Proust, and by Vogel in the blood. Carbonic acid gas likewise exists in the intestines of animals; but it is chiefly met with in animal bodies, in combination with the alkalies or earths; and it is emitted by all animals in the act of respiration.

2. *Hydrogen.*—This gas occurs universally in the animal kingdom. It is a constituent of all the fluids, and of many of the solids; and is generally in a state of combination with carbon. In the human intestines it has been found pure, as well as combined with carbon and sulphur.

3. *Carbon.*—This substance is met with, under various forms, in both fluids and solids. It is most frequently found under that of carbonic acid.

4. *Azote.*—This gas is likewise widely distributed as a component part of animal substances. Indeed, so generally does it prevail, that it often affords, as we have seen, a distinctive mark by which they may be known from vegetables. It likewise occurs, in an uncombined state, in the swim-bladder of certain fishes.

5. *Phosphorus* is found united with oxygen—in the state of *phosphoric acid*—in many of the solids and fluids. This is the acid, that is combined with the earthy matter of bones, and with potassa, soda, ammonia, and magnesia, in other parts. It is supposed to give rise

to the luminousness of certain animals—as of the fire-fly, the *Pyrosoma atlanticum*, &c.—but nothing precise is known on this subject.

6. *Calcium.*—This metal is found only in the state of oxide in the animal economy; and it is generally united with the phosphoric or carbonic acid. It is the earth, of which the hard parts of animals are constituted.

7. *Sulphur* is not met with extensively in the animal solids or fluids; nor is it ever found free, but always in combination with oxygen, united to soda, potassa, or lime. It seems to be an invariable concomitant of albumen, and is found, in the lower part of the intestines, in the form of sulphuretted hydrogen gas; and as an emanation from fetid ulcers. Brugmans indeed maintains, but on fallacious grounds, that this gas is the vehicle of the contagious principle in hospital gangrene.

8. *Iron.*—This metal has been detected in the colouring matter of the blood; in bile, and in milk. For a long time it was considered to be, in the first of these fluids, in the state of phosphate or sub-phosphate. Berzelius, however, showed, that this was not the case; that the ashes of the colouring matter always yielded oxide of iron in the proportion of 1–200th of the original mass. That distinguished chemist was, however, unable to detect the condition in which the metal exists in the blood, and could not discover its presence by any of the liquid tests. More recently, Engelhart, a German chemist, has shown, that the fibrine and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron, whilst he could procure it from the red globules by incineration. He also succeeded in proving its existence in the red globules by liquid tests, and his experiments have been repeated, with the same results, by Rose of Berlin. In milk, iron seems to be in the state of phosphate.

9. *Manganese* has been found in the state of oxide, along with iron, in the ashes of the hair.

10. *Silicium.*—Silica is found in the hair, urine, and in urinary calculi.

11. *Chlorine.*—In combination with hydrogen, and forming *muriatic acid*, chlorine is met with in most of the animal fluids. It is generally united with soda. Free *muriatic acid* has also been found by Prout in the stomach of the rabbit, hare, horse, calf, and dog; and he has discovered the same acid in the sour matter ejected from the stomachs of those labouring under indigestion. Mr. Children has made similar observations, and Messrs. Tiedemann and Gmelin, Professor Emmet, and the author have found it in considerable quantity, in the healthy gastric secretions of man.

12. *Sodium.*—The oxide of sodium, *soda*, forms a part of all the fluids. It has never been discovered in a free state, but is united, (without an acid,) to albumen. Most frequently, it is combined with the muriatic and phosphoric acids; less so, with the lactic, carbonic, and sulphuric acids.

13. *Potassium.*—The oxide, *potassa*, is found in many animal fluids, but always united with acids—the sulphuric, muriatic, phosphoric, &c. It is much more common in the vegetable kingdom, and hence one of its names—*vegetable alkali.*

14. *Magnesium.*—The oxide, *magnesia*, exists sparingly in bones, and in some other parts, but always in combination with the phosphoric acid.

The ORGANIC ELEMENTS, *proximate principles*, or *compounds of organization* are the primary combination of two or more of the elementary substances, in definite proportions. Formerly, four only were admitted—*gelatine, fibrine, albumen*, and *oil.* Of late years, however, organic chemistry has pointed out numerous others, which are divided into two classes—*first*, those that contain azote, as albumen, gelatine, fibrine, osmazome, mucus, caseine, urea, uric acid, the red colouring principle of the blood, the yellow colouring principle of the bile, &c.; and *secondly*, those that do not contain azote, as oleine, stearine, the fatty matter of the brain and nerves, the acetic, oxalic, benzoic, and lactic acids, the sugar of milk, sugar of diabetes, picromel, the colouring principle of the bile, and that of other solids and liquids.

I. *Organic Elements that contain Azote.*

1. *Albumen.* This is one of the most common organic constituents, and appears under two forms—*liquid* and *concrete.* In its purest state, the former is met with in the white of egg—whence its name—in the serum of the blood, the lymph of the absorbents, the serous fluid of the great splanchnic cavities and of the cellular membrane, and in the synovial secretion. It is colourless and transparent, without smell or taste, and is coagulated by acids, alcohol, ether, metallic solutions, and infusion of galls, and by a temperature of 165° Fahrenheit.

Concrete, coagulated, or *solid albumen* is white, tasteless, and elastic; insoluble in water, alcohol, or oil, but readily soluble in alkalies.

Albumen is always combined with soda. It consists of carbon, 52.883; oxygen, 23.872; hydrogen, 7.540; and azote, 15.705.

In both forms it exists, in abundance, in different parts of the animal body. Hair, nails, and horn consist of it. It is, in some form or other, the great constituent of tumours.

2. *Gelatine.*—This is the chief constituent of the cellular tissue, skin, tendons, ligaments, and cartilages. The membranes and bones also contain a large quantity of it. It is obtained by boiling these substances, for some time, in water; clarifying the concentrated solution; allowing it to cool, and drying the substance, thus obtained, in the air. In this state it is called *glue;* in a more liquid form, *jelly.* Gelatine dissolves readily in hot water: it is soluble in acids and alkalies; insoluble in alcohol, ether, and in the fixed

and volatile oils. Alcohol precipitates it from its solution in water. It consists of carbon, 47.881; hydrogen, 7.914; oxygen, 27.207; and azote, 16.998.

Gelatine, nearly in a pure state, forms the air-bag of different kinds of fishes, and is well known under the name of *isinglass*. It is used also extensively in the arts, under the forms of *glue* and *size*, on account of its adhesive quality. What is called *portable soup* is dried jelly, seasoned with various spices.

3. *Fibrine*.—This proximate principle exists in the chyle; enters into the composition of the blood; forms the chief part of muscular flesh, and may be looked upon as one of the most abundant animal substances. It is obtained by beating the blood, as it issues from a vein, with a rod. The fibrine attaches itself to each twig in the form of red filaments, which may be deprived of their colour by repeated washings with cold water. Fibrine is solid, white, flexible, slightly elastic, insipid, inodorous, and heavier than water. It is neither soluble in water, alcohol, nor acids; it dissolves in liquid potassa or soda, in the cold, without much change; but, when warm, becomes decomposed.

Fibrine consists of carbon, 53.360; oxygen, 19.685; hydrogen, 7.021; azote, 19.934. It constitutes the buffy coat of blood; and is thrown out from the blood-vessels, as a secretion, in many cases of inflammation, becoming subsequently organized, or penetrated by blood-vessels and nerves.

4. *Osmazome*. This is the *matière extractive du bouillon*, *extractive, and saponaceous extract of meat*.—When flesh, cut into small fragments, is macerated in successive portions of cold water, the albumen, osmazome, and salts are dissolved; and, on boiling the solution, the albumen is coagulated. From the liquid remaining, the osmazome may be procured in a separate state, by evaporating to the consistence of an extract, and treating with cold alcohol. This substance is of a reddish-brown colour, and is distinguished from the other animal principles by solubility in water and alcohol,—whether cold or at the boiling point,—and by not forming a jelly when its solution is concentrated by evaporation.

Osmazome exists in the muscles of animals, in the blood, and in the brain. It gives the peculiar flavour of meat to soups; and, according to Fourcroy, the brown crust of roast meat consists of it.

5. *Mucus*.—This term has been applied to various substances; and hence the discordant characters ascribed to it. Applying it to the fluid secreted by mucous surfaces, it varies somewhat according to the source whence it is derived. Its leading characters may be exemplified in that derived from the nostrils, which has the following properties.—It is insoluble in alcohol and water, but imbibes a little of the latter, and becomes transparent. It is neither coagulated by heat, nor rendered horny; but is coagulated by tannin.

Mucus, in a liquid state, serves as a protecting covering to different parts. Hence it differs somewhat in its characters, according to the office it has to fulfil. When inspissated, it forms, according to some, the minute scales that are detached from the surface of the body by friction, the corns, and the thick layers on the soles of the feet, the nails, and horny parts; and it is contained in considerable quantity in the hair, in wool, feathers, scales of fishes, &c.

6. *Caseum* or *Caseine*, or *Caseous matter.*—This substance exists only in milk, and is the basis of cheese. To obtain it, milk must be left at rest, at the ordinary temperature, until it is coagulated; the cream that collects on the surface must be taken off; the clot well washed with water, drained upon a filter, and dried. The residuum is pure *caseum.* It is a white, insipid, inodorous substance, insoluble in water, but readily soluble in the alkalies, especially in ammonia. It possesses considerable analogy with albumen. Proust ascribes the characteristic flavour of cheese to the presence of the caseate of ammonia.

Caseine consists of carbon, 59.781; oxygen, 11.409; hydrogen, 7.429; azote, 21.381.

7. *Urea.*—This proximate principle exists in the urine of the mammalia when they are in a state of health. In human urine it is less abundant after a meal, and it nearly disappears in diabetes, and in affections of the liver. It is obtained by evaporating urine to the consistence of syrup. It is then treated with four parts of alcohol, which are afterwards volatilized by heating the alcoholic extract. The mass, that remains, is dissolved in water, or rather in alcohol, and crystallized.

The purest urea that has been obtained assumes the shape of acicular prisms, similar to those of the muriate of strontian. It is colourless, devoid of smell, or of action on blue vegetable colours, transparent, and somewhat hard. Its taste is cool, slightly sharp, and its specific gravity greater than that of water. According to Bérard, it consists of oxygen, 26.40; azote, 43.40; carbon, 19.40; and hydrogen, 10.80.

8. *Uric or lithic acid.*—This acid is found in the urine of man, birds, serpents, tortoises, crocodiles, lizards, in the excrements of the silk-worm, and very frequently in urinary calculi. It is obtained by dissolving any urinary calculus which contains it, or the sediment of human urine, in warm liquid potassa, and precipitating the uric acid by the muriatic. Pure uric acid is white, tasteless, and inodorous. It is insoluble in alcohol, and is dissolved very sparingly by cold or hot water, requiring about 10,000 times its weight of that fluid, at 60° of Fahrenheit, for solution. It consists of carbon, 36; hydrogen, 2; oxygen, 24; nitrogen, 28; in ninety parts. The *xanthic acid*, found by Marcet in urinary calculi, seems to have been this acid.

9. *Red colouring principle of the blood.*—It has been already observed, that Engelhart and Rose, German chemists, had detected iron in the red globules of the blood, and had not found it in the other principles of that fluid. It has been considered probable, there-

fore, that it has something to do with the colour. Engelhart's experiments have not, however, determined the manner in which it acts, nor in what state it exists in the blood. The sulpho-cyanic acid, which is found in the saliva, forms, with the peroxide of iron, a colour exactly like that of venous blood; and it is not improbable but that the colouring matter may be found to be a sulpho-cyanate of iron.

To obtain the red colouring matter, allow the crassamentum or clot, cut into thin pieces, to drain as much as possible on bibulous paper, triturating it with water, and then evaporating the solution, at a temperature not exceeding 122° of Fahrenheit. When thus prepared, the colouring particles are no longer of a bright red colour, and their nature is somewhat modified, in consequence of which they are insoluble in water. When half dried, they form a brownish-red, granular, friable mass; and, when completely dried, at a temperature between 167° and 190°, the mass is tough, hard, and brilliant.

10. *Yellow colouring principle of the Bile.*—This substance is present in the bile of nearly all animals. It enters into the composition of almost all gall-stones, and is deposited in that organ under the form of magma. It is solid, pulverulent when dry, insipid, inodorous, and heavier than water. When decomposed by heat, it yields carbonate of ammonia, charcoal, &c. It is insoluble in water, in alcohol, and the oils, but is soluble in the alkalies.

II. *Organic Elements that do not contain Azote.*

1. *Oleine and Stearine.*—Fixed oils and fats are not pure proximate principles, as was at one time supposed. They consist of two substances, one of which is solid at the ordinary temperature of the atmosphere, and the other fluid: the former of these is called *Stearine*, from στεαρ, suet,—the latter *Elaïne*, or *Oleine*, from ελαιον, oil. Stearine is the chief ingredient of vegetable and animal suet, of fat and butter, and is found, although in small quantity, in the fixed oils. In the suety bodies, it is the cause of their solidity. Elaine and stearine may be separated from each other by exposing fixed oil to a low temperature, and pressing it, when congealed, between folds of bibulous paper. The stearine is thus obtained in a separate form, and by pressing the bibulous paper under water, an oily matter is procured, which is elaine in a state of purity. The stearine of mutton fat consists of carbon, 78.776; hydrogen, 11.770; and oxygen, 9.454:—the oleine of hog's lard, of carbon, 79.030; hydrogen, 11.422; and oxygen, 9.548.

2. *Fatty matter of the Brain and Nerves.*—Vauquelin found two varieties of fatty matter in the brain,—the one white, the other red, the properties of which have not been fully investigated. Both possess the singular property of giving rise to phosphoric acid by calcination, without there being any evidence of an acid or a phosphate in their composition. They may be obtained by repeatedly boiling

the cerebral substance in alcohol, filtering at each time, mixing the various liquors, and suffering them to cool:—a lamellated substance is deposited, which is the *white fatty matter*. By then evaporating the alcohol, which still contains the red fatty matter and osmazome, to the consistence of *bouillie*, and exposing this, when cold, to the action of alcohol, the osmazome is entirely dissolved, whilst the alcohol takes up scarcely any of the *red fatty matter*.

3. *Acetic acid.*—This acid exists in a very sensible manner in the sweat, urine, and in milk,—even when entirely sweet. It is formed in the stomach in indigestion; has been found by Professor Emmet and the author to be contained in the gastric secretions in health, and is one of the constant products of the putrid fermentation of animal or vegetable substances. It consists, according to Gay Lussac and Thénard, of carbon, 50.224; oxygen, 44.147; and hydrogen, 5.629. It is the most prevalent of the vegetable acids, and the most easily formed artificially.

4. *Oxalic acid.*—This acid,—which exists extensively in the vegetable kingdom, but always united with lime, potassa, soda, or oxide of iron,—is only found as an animal constituent in certain urinary calculi, combined with lime. It is formed of carbon, one part, oxygen, two parts.

5. *Benzoic acid.*—This acid, found in many individuals of the vegetable kingdom, is likewise met with in the urine of the horse, cow, camel, rhinoceros; and sometimes in that of man, especially of children. It consists of carbon, 74.71; oxygen, 20.02; hydrogen, 5.27.

6. *Lactic acid.*—The *acid of milk* is met with in the blood, urine, milk, marrow, and also in muscular flesh. Sometimes it is in a free state, but usually united with the alkalies. However much it may be concentrated, it does not crystallize, but remains under the form of syrup or extract. When cold it is tasteless, but when heated has a sharp acid taste. It is proper to observe, that this acid, although described by Berzelius, has not been universally admitted by chemists. Berzelius himself, indeed, now considers it to be acetic acid, disguised by animal matter; and Tiedemann and Gmelin are of the same opinion.

7. *Sugar of milk.*—This substance is so called, because it has a saccharine taste, and exists only in milk. It differs from sugar in not fermenting. It is obtained by evaporating whey, formed during the making of cheese, to the consistence of honey; allowing the mass to cool, dissolving it, clarifying, and crystallizing. It commonly crystallizes in regular parallelopipedons, terminated by pyramids with four faces. It is white, semi-transparent, hard, and of a slightly saccharine taste, and is formed of carbon, 38.825; oxygen, 53.834; and hydrogen, 7.341.

8. *Sugar of diabetes.*—In the disease, called *diabetes mellitus*, the urine, which is passed in enormous quantity, contains, at the expense of the economy, a large quantity of peculiar saccharine matter, which,

when properly purified, appears identical, both in properties and composition, with vegetable sugar, approaching nearer to the sugar of grapes than to that of the cane. It is obtained in an irregularly crystalline mass, by evaporating diabetic urine to the consistence of syrup, and keeping it in a warm place for several days. It is purified by washing in cold, or, at the most, gently heated alcohol, till the liquor comes off colourless, and then dissolving it in hot alcohol. By repeated crystallization it is thus rendered pure. (Prout.) In the notes of two cases of diabetes mellitus now before us, we find that sixteen ounces of the urine of one of the patients, of the specific gravity 1.034, afforded a straw-coloured extract, which, when cold and consolidated, weighed one ounce and five drachms. The same quantity of the urine of the other patient, specific gravity 1.040, yielded one ounce and seven drachms. Neither extract appeared to contain urea when nitric acid was added, but when a portion was dissolved in water, and subjected to a temperature of 212°, traces of ammonia were manifested on the vapour being presented to the fumes of muriatic acid. From this, a conclusion was drawn that urea was present, as it is the only known animal matter, which is decomposed by the heat of boiling water. During a little more than one month that the subject of the latter case was under care, he passed about four hundred and eighty pints of urine, or about seventy-five pounds troy of diabetic sugar! much of this being derived from the system itself. According to the analysis of Gay Lussac and Thénard, this sugar consists of hydrogen, 7.341; carbon, 38.825; oxygen, 53.834.

9. *Picromel.*—Thénard discovered this principle in the bile of the ox, sheep, dog, cat, and of several birds; Chevallier, in that of man. To obtain it, the acetate of lead of commerce must be added to bile until there is no longer any precipitate. By this means, the yellow matter of the bile and the whole of the fatty matter are thrown down, united with the oxide of lead; the phosphoric acid—of the phosphate of soda, and the sulphuric acid—of the sulphate of soda, are likewise precipitated. The picromel may then be thrown down from the filtered liquor by the subacetate of lead. The precipitate, which is a combination of picromel with oxide of lead, must now be washed and dissolved in acetic acid. Through this solution, sulphuretted hydrogen is passed to separate the lead; the solution is then filtered, and the acetic acid driven off by evaporation.

Pure picromel is devoid of colour, and has the same appearance and consistence as thick turpentine. Its taste is at first acrid and bitter, but afterwards sweet. Its smell is nauseous, and its specific gravity greater than that of water. When digested with the resin of the bile, a portion of the latter is dissolved, and a solution is obtained, which has both a bitter and a sweet taste, and yields a precipitate with the subacetate of lead and the stronger acids. This is the compound that causes the peculiar taste of the bile. According to Thomson, Picromel is composed of carbon, 54.53; oxygen, 43.65; and hydrogen, 1.82

10. *Colouring principle of the bile.*—Of the nature of this principle, which exists in the bile of different animals, we have no definite ideas. It is generally precipitated along with the fatty matter; and, by means of ether, which dissolves it, may be obtained pure.

The colouring principles of other parts of animals are not sufficiently known to admit of classification.

These inorganic and organic elements, variously combined and modified by the vital principle, constitute the different parts of the animal fabric. Chemistry, in its present improved condition, enables us to separate them, and to investigate their properties; but all the information we derive from this source relates to bodies, that have been influenced by the vital principle, but are no longer so; and in the constant mutations, that are occurring in the system whilst life exists, and under its controlling agency, the same textures might exhibit very different chemical characteristics, could our researches be directed to them under those circumstances. Whenever, therefore, the physiologist has to apply chemical elucidations to operations of the living machine, he must recollect, that all his analogies are drawn from dead matter—a state so widely differing from the living as to suggest to him the necessity of a wise and discriminating caution.

The components of the animal body are invariably found under two forms—solids and fluids. Both of these are met with in every animal, the former being derived from the latter; for, from the blood every part of the body is separated; yet they are mutually dependent, for every liquid is contained in a solid. The blood itself circulates in a solid vessel: both, too, possess an analogous composition, are in constant motion, and are incessantly converted from one into the other. Every animal consists of a union of the two, and this union is indispensable to life. Yet certain vague notions, with regard to their relative preponderance in the economy, and to their agency in the production of disease, have led to very discordant doctrines of pathology,—the *solidists* believing, that the cause of most affections is resident in the solids; the *humorists*, that we are to look for it in the fluids. In this, as in similar cases, the mean will lead to the most rational result. The causes of disease ought not to be sought in the one or the other exclusively.

Of the solid parts of the Human Body.

A *solid* is a body, whose particles adhere to each other, so that they will not separate by their own weight, but require the agency of some extraneous force to effect the separation. Anatomists reduce all the solids of the human body to twelve varieties:—*bone, cartilage, muscle, ligament, vessel, nerve, ganglion, follicle, gland, membrane, cellular membrane*, and *viscus*.

1. *Bone* is the hardest of the solids. It forms the skeleton—the

levers for the various muscles to act upon, and serves for the protection of important organs.

2. *Cartilage* is of a white colour, formed of very elastic tissue, covering the articular extremities of bones to facilitate their movements; sometimes added to bones to prolong them, as in the case of the ribs; at others, placed within the articulations, to act as elastic cushions; and, in the fœtus, forming a substitute for bone; hence cartilages are divided into *articular* or *incrusting*, *cartilages of prolongation*, *interarticular cartilages*, and *cartilages of ossification*.

3. The *muscles* constitute the flesh of animals. They consist of fasciculi of red and contractile fibres, extending from one bone to another, and are the agents of all movements.

4. The *ligaments* are very tough, difficult to tear, and, under the form of cords or membranes, serve to connect different parts with each other, particularly the bones and muscles; hence their division, by some anatomists, into *ligaments of the bones*—as the ligaments of the joints, and into *ligaments of muscles*—as the tendons and aponeuroses.

5. The *vessels* are solids, having the form of canals, in which the fluids circulate. They are called, according to the fluid they convey, *sanguineous*, (*arterial and venous*,) *chyliferous*, *lymphatic*, and *secretory vessels*.

6. The *nerves* are solid cords, consisting of numerous fasciculi. These are connected with the brain, spinal marrow, or great sympathetic; and they are the organs by which impressions are conveyed to the nervous centres, and by which each part is endowed with vitality. There are three great divisions of the nerves, those of *motion*, *sensation*, and *expression*.

7. A *ganglion* is a solid knot, situated in the course of a nerve, and seeming to be formed by an inextricable interlacing of the nervous filaments. The term is likewise applied, by many modern anatomists, to a similar interlacing of the ramifications of a lymphatic vessel. *Ganglions* may, consequently, either be *nervous* or *vascular;* and the latter, again, may be divided into *chyliferous* or *lymphatic*, according to the kind of vessel in which they may appear. Professor Chaussier, a distinguished anatomist and physiologist, has given the name *glandiform ganglions* to certain organs, whose nature and functions are unknown to us, but which he considers to be organs for the admixture and elaboration of fluids,—as the thymus gland, the thyroid gland, &c.

8. *Follicles* or *crypts* are secretory organs, shaped like membranous ampullæ or vesicles, always seated in the substance of one of the outer membranes of the body—the skin or the mucous surfaces, and secreting a fluid intended to lubricate them. They are often divided into the *simple* or *isolated*, the *conglomerate*, and the *compound*, according to their size, or the number in which they are grouped and united together.

9. The *gland* is also a secretory organ, but differing from the last. The fluid, secreted by it, is of greater or less importance. Its organization is more complex than that of the follicle; and the fluid, after secretion, is poured out by means of one or more excretory ducts.

10. *Membrane.*—This is one of the most extensive and important of the substances formed by the cellular tissue. It is spread out in the shape of a web, and, in man, serves to line the cavities and reservoirs, and to form, support, and envelope all the organs.

Bichat divides membranes into two kinds, the *simple* and *compound*, according as they are formed of one or more layers.

The simple membranes are of three kinds, the *serous*, *mucous*, and *fibrous*.

1*st.* The *serous membranes* are those that constitute all the sacs or shut cavities of the body, those of the chest and abdomen, for example.

2*dly.* The *mucous*, or those that line all the outlets of the body,—the air passages, alimentary canal, urinary and genital organs, &c.

3*dly. Fibrous membranes*, or those which compose tendon, aponeurosis, ligament, &c.

The *compound membranes* are formed by the union of the simple, and are divided into *sero-fibrous*, as the pericardium; *sero-mucous*, as the gall-bladder, at its lower part; and *fibro-mucous*, as the ureters.

In the view of Raspail, the truly simple animal membrane is the parietes of a vesicle. In this state of simplicity it is so transparent, that it is only perceptible by the plaits or folds it forms on being moved, but if it were a compound membrane, the rays of light would be reflected. On this ground he disputes the accuracy of the observations of Sir Everard Home, Edwards, and others, maintaining that the pretended globules, seen and figured by them, were optical illusions, produced by the play of light on the different folds of the membrane.

11. The *cellular* or *laminated tissue*—to be described presently—is a sort of spongy or areolar structure, which forms the framework of all the solids, fills up the spaces between them, and serves, at the same time, as a bond of union and of separation.

12. The *viscus* is the most complex solid of the body, not only as regards intimate organization but use. This name is given to organs contained in the splanchnic cavities,—brain, thorax, and abdomen;—and hence called *cerebral*, *thoracic*, or *abdominal*.

Every animal solid is either *amorphous* or *fibrous;* that is, it is either without apparent arrangement, like jelly, or it is disposed in minute threads, which are called fibres. The disposition of these threads, in different structures, is various. Sometimes, they retain the form of threads; at others, they have that of laminæ, lamellæ, or plates. Accordingly, when we examine any animal solid, where the organization is perceptible, it is found to be either amorphous, or fibrous and laminated.

This circumstance led the ancients to endeavour to discover an *elementary fibre*, or *filament*, from which all the various organs might be formed. Haller embraced the idea, and endeavoured to unravel every texture to this ultimate element,—asserting that it is to the physiologist what the line is to the geometer; and that, as all figures can be constructed from the line, so every tissue and organ of the body may be built up from the *filament*. Haller, however, admits, that his elementary fibre is not capable of demonstration, and that it is visible only to the "mind's eye,"—"*invisibilis est ea fibra, solâ mentis acie distinguimus.*" It must be regarded, indeed, as a pure abstraction; for, as different animal substances have different proportions of carbon, hydrogen, oxygen and azote, it is fair to conclude, that the elementary fibre must differ also in the different structures.

The ancients believed, that the first product of the elementary fibre was cellular tissue, and that this tissue formed every organ of the body;—the difference in the appearance of these organs arising from the different degrees of condensation of its laminæ.

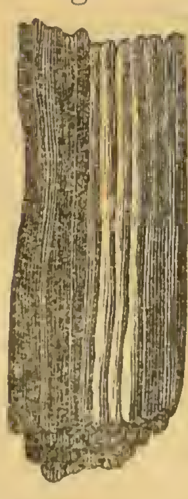
Anatomists, however, have been unable to reduce all the animal solids to cellular tissue solely.

In the upper classes of animals, three *primary fibres* or *tissues*, or anatomical elements, are usually admitted,—the *cellular* or *laminated*, the *muscular*, and the *nervous*, *pulpy*, or *medullary*.

1. The *cellular or laminated fibre or tissue.*—This is the most simple and abundant of the animal solids. It exists in every organized being, and is an element of every other solid. In the enamel of the teeth only it has not been detected. It is formed of an assemblage of thin laminæ of delicate, whitish, extensible filaments, interlacing and leaving between each other areolæ or cells. (See Fig. 1.) These plates or filaments are neither sensible nor irritable, and are composed of concrete gelatine. The great bulk of animal solids consists of cellular tissue, arranged in the form of membrane.

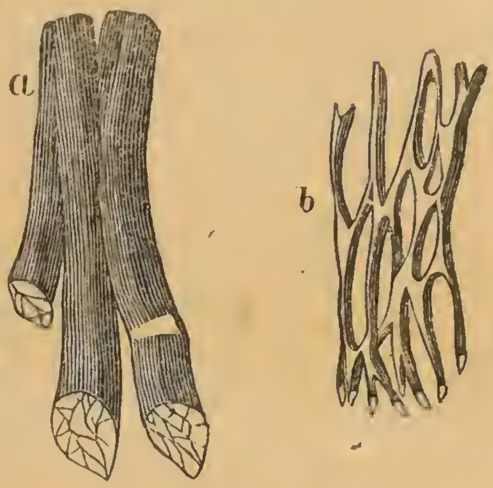
2. *Muscular fibre or tissue.*—This is a substance of a peculiar nature, arranged in fibres of extreme delicacy. The fibres are linear, soft, grayish or reddish, (see Fig. 2.) and possessed of irritability; that is, they move very perceptibly under the influence of mechanical or chemical stimuli. They are composed, essentially, of fibrine. Prochaska, a distinguished anatomist of Vienna, maintains, that the ultimate fibre or filament of muscular tissue is discernible; that it is, in every part, of the same magnitude—about $\frac{1}{50}$th part of the diameter of the red globule of the blood, or about $\frac{1}{3000000}$th part of an inch in diameter. It is probable, however, that were our means of examining minute objects still further improved, we should be able to detect a filament even more delicate than this.

Fig. 2.



The muscular fibres, which are arranged in the form of membranous expansions or muscular coats, differ from proper muscles chiefly in the mechanical arrangement of their fibres. (Fig. 3, *a* & *b*.) The physical and chemical characters of both are identical. The fibres, instead of being collected into fasciculi, are in layers, and, instead of being parallel, interlace. This tissue does not exist in the zoophytes.

Fig. 3.



3. *Nervous, pulpy, or medullary fibre or tissue.*—This tissue is much less distributed than the preceding. It is of a pulpy consistence, is composed essentially of albumen united to a fatty matter, and is the organ of sensibility, or for receiving and transmitting impressions to the mind. Of it, the brain, cerebellum, medulla spinalis, nerves and their ganglia are composed. The ultimate nervous filament is considered by Fontana, Reil, and others, to be about twelve times larger than the ultimate muscular filament. The same remarks, however, may be made here concerning our limited means of observation, that were made on the elementary muscular fibre.

Professor Chaussier has added another primary fibre or tissue,—the *albugineous.* It is white, satiny, very resisting, of a gelatinous nature, neither sensible nor irritable, and constitutes the tendons and tendinous structures. Chaussier is, perhaps, the only anatomist that admits this tissue. Others regard it as a very condensed variety of the cellular.

These various fibres or tissues, by uniting differently, constitute the first order of solids; and these again, by union, give rise to *compound solids,* from which the different organs, bones, glands, &c. are formed. A bone, for example, is a compound of various tissues, *osseous* in its body, *medullary* in its interior, *fibrous* externally, and *cartilaginous* at its extremities.

Bichat was the first anatomist, who possessed any clear views regarding the constituent tissues of the animal frame; and whatever merit may accrue to after anatomists and physiologists, he is entitled to the credit of having pointed out the path, and facilitated the labours of the anatomical analyst. The following table exhibits the compound tissues generally admitted.

SYSTEMS.	1. Cellular.	
	2. Vascular - - - -	*Arterial.* *Venous.* *Lymphatic.*
	3. Nervous - - - -	*Cerebral.* *Ganglionic.*
	4. Osseous.	

Systems.	5. Fibrous - - - -	*Fibrous.*
		Fibro-cartilaginous.
		Dermoid.
	6. Muscular - - - -	*Voluntary.*
		Involuntary.
	7. Erectile.	
	8. Mucous.	
	9. Serous.	
	10. Corneous or Epidermic -	*Pileous.*
		Epidermoid.
	11. Parenchymatous - -	*Glandular.*

In combining to form the different structures, the solids are arranged in a variety of ways. Of these, the chief are in filaments or elementary fibres, tissues, organs, apparatuses, and systems.

The *filament*, we have seen, is the elementary solid. A *fibre* consists of a number of filaments united together. Occasionally, this is called a *tissue*:—the term *tissue* usually, however, means a particular arrangement of fibres. An *organ* is a compound of several tissues. An *apparatus* is an assemblage of organs, concurring to the same end:—the *digestive apparatus* consists of the organs of mastication, insalivation, and deglutition, of the stomach, duodenum, pancreas, liver, chyliferous vessels, &c. These organs may be, and are of very dissimilar character, both as regards their structure and functions; but, if they concur in the same object, they form an *apparatus*. A *system*, on the other hand, is an assemblage of organs, all of which possess the same or an analogous structure. Thus, all the muscles of the body have a common structure and function, and they constitute, in the aggregate, the *muscular system*. All the vessels of the body, and all the nerves, for like reasons, constitute respectively the *vascular*, and the *nervous systems*.

Of the Fluids of the Human Body.

The positive quantity or proportion of the fluids in the human body does not admit of easy appreciation, as it must obviously vary at different periods, and under different circumstances. The younger the animal, the greater is the preponderance. When we first see the embryo, it appears to be almost entirely fluid. As it becomes gradually developed, the solid parts increase in their relative proportion, until the adult age; after which the proportion becomes less and less as the individual advances in life. During the whole of existence, too, the quantity of fluids in the body fluctuates. At times, there is plethora or unusual fulness of vessels; at others, the blood is less in quantity. Experiments have been made for the purpose of ascertaining the relative proportion of the fluids to the solids. Richerand says, that they are in the ratio of six to one; Chaussier, of nine to one. The latter professor put a dead body, weighing one hundred and twenty pounds, into a heated oven, and dried it. After desiccation, it was found to be reduced to twelve pounds. It is probable, however, that some of the more solid portions were driven off by the heat employed, and hence, that the evaluation of the proportion of the fluids was too high. In the Egyptian mummies, which are completely deprived of fluid, the solids are extremely light, not weighing more than seven pounds; but, as we are ignorant of the original weight of the body, we cannot arrive at any comparative approximation. The dead bodies, found in the arid sands of Arabia, as well as the dried preparations of the anatomical theatre, afford additional instances of this reduction by desiccation. To a less extent, we have the same thing exhibited in the excessive diminution in weight, which occurs in disease, and occasionally in those who are apparently in health. Not many years ago, an *anatomie vivante* was exhibited, in London, to the gaze of the curious and scientific, whose weight was not more than eighty pounds. Yet the ordinary functions were carried on, apparently unmodified. In the year 1830, a still more wonderful phenomenon was exhibited in New York, who was called the "*living skeleton*." This extraordinary being was forty-two years old, five feet two inches high, and weighed but sixty pounds. His weight had formerly been one hundred and thirty-five pounds. For sixteen years previously, he had been gradually losing flesh, without any apparent disease, having enjoyed perfect health and appetite, and eating, drinking, and sleeping as well as any one. We have it also on the authority of Captain Riley, that, after protracted sufferings in Africa, he was reduced from two hundred and forty pounds to below ninety!

The fluids are variously contained; sometimes in vessels—as the blood and lymph; at others, in cavities—as the fluids secreted by the pleura, peritoneum, arachnoid coat of the brain, &c.; others are in minute areolæ—as the fluid of the cellular membrane; whilst others again are intimately combined with the solids.

They differ likewise in density, some existing in the state of halitus or vapour; others are very thin and aqueous—as the fluid of the serous membranes; others of more consistence—as the secretion of the mucous membranes, the animal oils, &c.

The physical and chemical properties of the fluids will engage our attention when they fall individually under consideration, and we shall find that one of them at least—the blood—exhibits certain phenomena analogous to those of the living solid.

The fluids have been differently classed, according to the particular views that have from time to time prevailed in the schools. The ancients referred them all to four—blood, bile, phlegm or pituita, and atrabilis; and each of these was conceived to abound in one of the four ages, seasons, climates, or temperaments. The blood predominated in youth, in the spring, in cold mountainous regions, and in the sanguine or inflammatory temperament. The pituita or phlegm had the mastery in old age, in winter, in low and moist countries, and in the lymphatic temperament. The bile predominated in mature age, in summer, in hot climates, and in the bilious temperament; and lastly, the atrabilis was the characteristic of middle age, of autumn, of equatorial climes, and of the melancholic temperament. This was their grand humoral system, which has vanished before a better observation of facts, and more improved methods of physical and metaphysical investigation. The atrabilis was a creature of the imagination; the pituitous condition is unintelligible to us; and the doctrine of the influence of the humours on the ages, temperaments, &c. is irrational.

Subsequently, the humours were classed according to their physical and chemical properties; for instance, they were divided into liquids, vapours, and gases; into acid, alkaline and neutral; into thick and thin; into aqueous, mucilaginous, gelatinous, and oily; into saline, oily, saponaceous, mucous, albuminous, and fibrinous, &c. In more modern times, endeavours have been made to arrange them, according to their uses in the economy, into 1, *recrementitial fluids*, or those intended to be again absorbed; 2, *excrementitial*, those that have to be expelled from the body; and 3, those which participate in both uses, and are hence termed *excremento-recrementitial*. Blumenbach divided them into crude humours, blood, and secreted humours, a division which has been partly adopted by Adelon; and lastly, Professor Chaussier, whose anatomical arrangements and nomenclature have rendered him justly celebrated, reckons five classes:—1, those produced by the act of digestion,—the chyme, and the chyle; 2, the circulating fluids,—the lymph and the blood; 3, the perspired fluids; 4, the follicular; and 5, the glandular. This arrangement has been adopted by Magendie, and is as satisfactory as any that has been proposed.

The following is an enumeration of the different fluids or humours of the body, all of which will have to engage attention hereafter.

1. The chyme and the chyle.
2. The blood and the lymph.
3. The *perspired* or *exhaled fluids*, including the serous fluids, the synovia, the fat, the medulla, the colouring matter of the skin, the colouring matters of the uvea and choroid of the eye, the three humours of the eye, the liquor of Cotugno, the cephalo-spinal fluid, the fluid of the lymphatic and glandiform ganglions, the humour exhaled from the interior of vessels, the liquor amnii, the water of the chorion and that of the umbilical vesicle, the cutaneous transpiration, the pulmonary transpiration, the perspired humours of the digestive apparatus, and those of the urinary and genital organs. In the female, during the time she is capable of fecundation, a monthly exhalation takes place, called the catamenia, or menses; and, after delivery, a similar secretion occurs, called the lochia.
4. The *follicular fluids* are—the sebaceous humour of the skin, the cerumen, the humour of Meibomius, that of the caruncula lachry-

malis, the humour secreted at the base of the glands in the male, and within the vulva of the female, the humour of the mucous follicles of the respiratory, digestive, urinary, and genital apparatuses, including that of the tonsils, cardiac glands, prostate, Cowper's glands, &c.

5. The *glandular fluids* are—the tears, saliva, pancreatic juice, bile, urine, sperm, and milk.

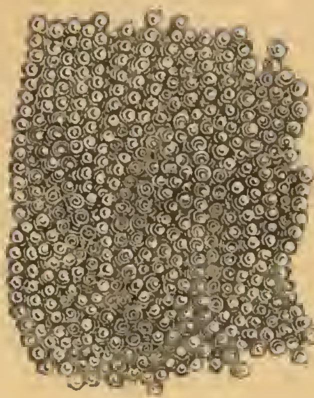
Of the Elementary Structure of Animal Substances.

Anatomists have not been content with endeavoring to reduce the different organized textures to primary fibres and filaments, but, by the aid of the microscope, they have attempted to discover the particular arrangement of the constituent corpuscles. The discovery of that valuable instrument gave the impulse, and very soon the scientific world was presented with the results obtained by numerous observers. These observations have been, from time to time, continued until the present day. It is, however, to be regretted, that our information, derived from this source, has not been as accurate as it would appear to admit of. From different quarters we have the most discordant statements, so as to exhibit clearly, either that the narrators have employed instruments of very different powers, or that they have been blinded, or had the vision depraved, by preconceived theories or hypotheses. One of the very first effects of the discovery of the microscope was the detection of a globular structure of the primitive tissues of the body, by Leeuenhoek, an announcement that gave rise to much controversy, which has continued indeed till the present time, and has engaged the attention particularly of Prochaska, Fontana, Sir Everard Home, Mr. Bauer, the brothers Wenzel, Dr. Milne Edwards, MM. Prévost and Dumas, Dutrochet, Hodgkin, Raspail, and others.

The observations and experiments of Dr. Edwards especially have occasioned much interesting speculation and inquiry. They may perhaps be taken as the foundation on which the believers in the globular structure now rest their opinions. The views of Dr. Edwards were first published in 1823, in a communication, entitled "*Mémoire sur la structure élémentaire des principaux tissus organiques des Animaux;*" and in a second article in the *Annales des Sciences Naturelles*, for December, 1826, entitled "*Recherches microscopiques sur la structure intime des tissus organiques des Animaux.*" He examined all the principal textures of the body, the cellular tissue, the membranes, tendons, muscular fibre, nervous tissue, the skin, the coats of the blood-vessels, &c.

When the cellular tissue was viewed through a powerful lens, it seemed to consist of cylinders; but, by using still higher magnifying powers, these cylinders were found to be formed of rows of globules, all of the same same size, that is, about the $\frac{1}{7500}$th or $\frac{1}{8000}$th of an inch in diameter; (Fig. 4.) separated from each

Fig. 4.

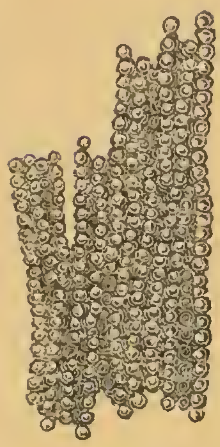


other, and lying in various directions; crossing and interlacing; some of the rows straight, others bent, and some twisted, forming irregular layers, united by a kind of net-work.

The membranes, which consist of cellular tissue, were found to present exactly the same kind of arrangement.

The muscular fibre, when examined in the like manner, was found to consist of globules also $\frac{1}{8000}$th part of an inch in diameter. Here, however, the rows of globules are always parallel. The fibres never intersect each other like those of the cellular tissue, and this is the only discernible difference, the form and size of the globules being alike. The size of the globules, and the linear arrangement they assume, seem to be the same in all animals that possess a muscular structure. (Fig. 5.)

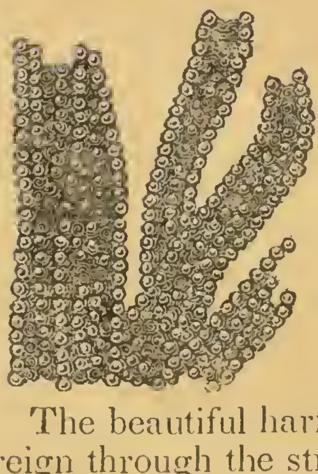
Fig. 5.



The nervous structure has, by almost all observers, been esteemed globular. The examination of Dr. Edwards yielded similar results. It seemed to be composed of lines of globules of the same size with those that form the cellular membrane and the muscles; but holding an intermediate place as to the regularity of their arrangement, and having a fatty matter interposed between the rows.

In regard to the size of the globules, Dr. Edwards differs materially from an accurate and experienced microscopic observer, Mr. Bauer, who asserts that the cerebral globules are of various sizes. (Fig. 6.)

Fig. 6.



From the results of his own diversified observations, Dr. Edwards concludes, that "spherical corpuscles, of the diameter of $\frac{1}{300}$th of a millimeter, constitute, by their aggregation, all the organic textures, whatever may be the properties, in other respects, of those parts, and the functions for which they are destined."

The beautiful harmony and simplicity, which would thus seem to reign through the structures of the animal body, have attracted great attention to the labours of Dr. Edwards. The vegetable kingdom was subjected to equal scrutiny; and, what seemed still more astounding, it was affirmed, that the microscope proved it also to be constituted of globules exactly like those of the animal, and of the same magnitude, $\frac{1}{8000}$th of an inch in diameter; hence, it was assumed, that all organized bodies possess the same elementary structure, and of necessity, that the animal and the vegetable are readily convertible into each other under favourable circumstances, and that they differ only in the greater or less complexity of their organization. Independently of all other objections, however, the animal differs, as we have seen, from the vegetable, in composition; and this difference must exist not only in the whole but in its parts; so that even were it demonstrated, that the globules of the beings of the two kingdoms are alike in size, it would by no means follow, that they should be identical in intimate composition.

The discordance, which we have deplored, is strikingly applicable to the case before us. The appearance of the memoir of Dr. Edwards excited the attention of Dutrochet, and in the following year his "*Researches*" on the same subject were published, in which he asserts, that the globules, which compose the different structures of the invertebrated animals, are considerably larger than those of the vertebrated; that the former appear to consist of cells, containing other globules still smaller; and hence he infers, that the globules of vertebrated animals are likewise cellular, and contain series of still smaller globules.

Dr. Edwards, in his experiments, found that the globules of the nervous tissue, whether examined in the brain, in the spinal cord, in the ganglia, or in the nerves, have the same shape and diameter, and that no difference can be distinguished in them, from whatever animal the tissue is taken. Dutrochet, on the other hand, considers, with Sir Everard Home and the brothers Wenzel, that the globules of the brain are cellules of extreme minuteness, containing a medullary or nervous substance, which is capable of becoming concrete by the action of heat and of acids. This structure, he remarks, is strikingly evidenced in certain molluscous animals; and he instances the small pulpy nucleus, forming the cerebral hemisphere of the *limax rufus*, and the *helix pomatia*, composed of globular, agglomerated cellules, on the parietes of which a considerable number of globular or ovoid corpuscles are perceptible. (Fig. 7.)

Fig. 7.

M. Dutrochet, again, has not found the structure of the nerves to correspond with that of the brain. He asserts, that the elementary fibres, which enter into their composition, do not consist simply of rows of globules, according to the opinion of Edwards and others, but that they are cylinders of a diaphanous substance, the surface of which is studded with globular corpuscles, and that, as these cover the whole surface of the cylinder, we are led to believe that they are situated internally. After detailing this difference of structure between the brain and the nerves, the former consisting chiefly of nervous corpuscles, the latter chiefly of cylinders or fibres, Dutrochet announces the hypothesis, which exhibits too many indications of having been formed prior to his microscopic investigations,—that these cerebral corpuscles are destined for the production of the nervous power, and that the nervous fibres are tubes, filled with a peculiar fluid, by the agency of which *nervi-*

motion is effected. For further developements of the analysis of Dutrochet, the reader is referred to the work itself, which exhibits all the author's ingenuity and enthusiasm, but can scarcely be considered historical.

The beautiful superstructure of Dr. Edwards, and the ingenuity of Dutrochet have, however, been most fatally assailed by subsequent experiments, with a microscope of unusual power, by Dr. Hodgkin. The globular structure of the animal tissues, so often developed, and apparently so clearly and satisfactorily established by Dr. M. Edwards, is, we are told by Dr. Hodgkin, a mere deception; and we have again to refer the most minute parts of the cellular membrane, muscles, and nerves to the striated or fibrous arrangement. A part of the discrepancy between Messrs. Edwards and Dutrochet may be explained by the fact of the former using an instrument of greater magnifying power than the latter, who employed the simple microscope only. It has been observed, that when Dr. Edwards used an ordinary lens, the arrangement of a tissue appeared cylindrical, which, with the compound microscope, was distinctly globular. The discordance between Messrs. Edwards and Hodgkin is reconcilable with more difficulty. On the whole subject, indeed, our minds must be kept in a state of doubt, and we must wait until the point is fully ascertained, if it is ever destined to be so. In our uncertainty regarding the existence of the globules themselves, it is hardly necessary to inquire into the opinion, professed by Messrs. Prévost and Dumas, and by Dr. Edwards, that all the proximate principles,—albumen, fibrine, gelatine, &c.—assume a globular form, whenever they pass from the fluid to the solid state, whatever may be the cause producing such conversion.

Still more recently, M. Raspail has ranged himself amongst those, who consider, that the ultimate structure of all organic textures is vesicular, and that the organic molecule, in its simplest form, is an imperforate vesicle, endowed with the faculty of inspiring gaseous and liquid substances, and of expiring again such of their decomposed elements, as it cannot assimilate;—properties, which he conceives it to possess under the influence of vitality.

Lastly, J. F. Meckel, from his observations, infers, that all the solids and fluids of the human body are formed of two elementary substances: *first*, of an amorphous matter, which is concrete in the former and fluid in the latter; and *secondly*, of globules. Of these two substances, the former may exist alone, and constitute some of the textures;—for instance, the cellular tissue, the bones, cartilages, &c. The globules, on the contrary, are always united with the amorphous substance, which, in the solids, serves as a bond of union, and in which the globules are immersed in the fluids. This anatomist believes that the globules differ in shape, size, and number, in different animals, and in different parts of the same animal, and even in the same part, according to age.

Physical Properties of the Tissues.

The tissues of the body possess the physical properties of matter in general. They are found to vary in consistence,—some being hard, and others soft, as well as in colour, transparency, &c. We find, also, certain physical properties, analogous, indeed, to what are met with in several inorganic substances, but generally superior in degree. These are *flexibility*, *extensibility*, and *elasticity*, which are variously combined and modified in the different forms of animal matter, but exist to a greater or less extent in every organ. *Elasticity* is only exerted under particular circumstances: when the part, for example, in which it is seated, is put upon the stretch or is compressed, the force of elasticity restores it to its primitive state, as soon as the distending or compressing cause is removed. The tissues, in which elasticity is inherent, are so disposed through the body, as to be kept in a state of distention by the mechanical circumstances of situation; but, as soon as these circumstances are deranged, elasticity comes into play, and produces shrinking of the substance. It is easy to see, that these circumstances, owing to the constant alteration in the relative situation of parts, must be ever varying. Elasticity is, therefore, constantly called into action, and in many cases acts upon the tissues as a new power. The cartilages of the ribs, joints, &c. are, in this manner, valuable agents in particular functions. We have other examples of the mode in which elasticity exhibits itself, under similar circumstances, when the contents of hollow parts are withdrawn, and whenever muscles are divided transversely. The gaping wound, produced by a cut across a shoulder of mutton, is familiar to all. Previous to the division, the force of elasticity is kept neutralized by the mechanical circumstances of situation,—or by the continuity of the parts; but as soon as this continuity is disturbed, or, in other words, as soon as the mechanical circumstances are altered, the force of elasticity is exerted and produces recession of the edges. This property has been described under various names. It has been called *tone*, or *tonicity*, *contractilité de tissu*, *contractilité par défaut d'extension*, *&c.*

The other properties—*flexibility* and *extensibility*—vary greatly according to the structure of the parts. The tendons, which are composed of the cellular tissue, exhibit very little extensibility, and this for wise purposes. They are the conductors of the force developed by the muscle, and were they to yield, it would be at the expense of the muscular effort; but they possess great flexibility. The articular ligaments are very flexible, and somewhat more extensible. On the other hand, the fibrous or ligamentous structures, which are employed to support weights, or which are antagonists to muscular action,—such as the *ligamentum nuchæ*, or the strong ligament, which passes from the spine to the head of the quadruped, —are very extensible and elastic.

Another physical property, possessed by animal substances, is a kind of contractility, accompanied with sudden corrugation and curling. This effect, which Bichat terms *racornissement*, is produced by heat and by chemical agents, especially by the strong mineral acids. The property is exhibited by leather when thrown into the fire.

An effect, in some measure resembling this, is caused by the evaporation of the water which is united to animal substances. This constitutes what Dr. Roget calls the *hygrometric property* of animal membranes. It is characteristic of dry, membranous structures, all of which are found to contract, more or less, by the evaporation of moisture, and to expand again by its re-absorption; hence the employment of such substances as *hygrometers*. According to Chevreul, many of the tissues are indebted for their physical properties to the water they contain, or with which they are imbibed. When deprived of this fluid, they become unfit for the purposes for which they are destined in life, and resume them as soon as they have recovered it.

A most important property, possessed by the tissues of organized bodies, is that of *imbibition;* a property to which attention has been chiefly directed of late years. If a liquid be put in contact with any organ or tissue, in process of time the liquid will be found to have passed into the areolæ of the organ or tissue, as it would enter the cells of a sponge. The length of time, occupied in this imbibition, will depend upon the nature of the liquid and the kind of tissue. Some parts of the body, as the serous membranes and small vessels, act as true sponges, absorbing with great promptitude: others resist imbibition for a considerable time,—as the epidermis.

Liquids penetrate equally from within to without: the process is then called *transudation*, but it does not differ from imbibition.

Within the last few years some singular facts have been observed regarding the imbibition of fluids and gases. On filling membranous expansions, as the intestine of a chicken, with milk or some dense fluid, and immersing it in water, Dutrochet observed that the milk left the intestine, while the water entered it; and hence he concluded, that whenever an organized cavity, containing a fluid, is immersed in another fluid, less dense than that which is in the cavity, there is a tendency in the cavity to expel the denser and absorb the rarer fluid. This Dutrochet terms *endosmose*, or "inward impulsion;" and he conceives it to be a new power,—a "physico-organic or vital action." Subsequent experiments showed that a reverse operation could likewise take place. If the internal fluid was rarer than the external, the transmission occurred in the opposite direction. To this reverse process, Dutrochet gives the name *exosmose*, or "outward impulsion."

Soon after the appearance of Dutrochet's essay, similar experiments were repeated, with some modifications, by Dr. Faust, and by Dr. Togno, of Philadelphia, and with like results. The fact of this imbibition and transudation was singular and impressive; and, with so enthusiastic an individual as Dutrochet, could not fail to give birth to numerous and novel conceptions. The energy of the action of both endosmose and exosmose is in proportion, he asserts, to the difference between the specific gravities of the two fluids; and also, independently of their gravity, their chemical nature affects their power of transmission. These effects—Dutrochet at once decided—must be owing to electricity. The cavities, in which the changes take place, he conceives to be like Leyden jars, having their two surfaces charged with opposite electricities, the ultimate effect or direction of the current being determined by the excess of the one over the other.

In an interesting and valuable communication by Dr. J. K. Mitchell, of Philadelphia, "on the penetrativeness of fluids," many of the visionary speculations of Dutrochet have been sensibly animadverted upon. It is there shown, that Dutrochet had asserted, in the teeth of some of his most striking facts, that the current was from a less dense to a more dense fluid; and that it was from positive to negative, dependent not on an inherent power of filtration, a power always the same when the same membrane is concerned, but modified at pleasure by supposed electrical agencies. This view was subsequently abandoned by M. Dutrochet, in favour of the following principle. It is well known that porous bodies, as sugar, wood, or sponge, are capable of imbibing liquids, with which they are brought in contact. In such case the liquid is not merely introduced into the pores of the solid, as it would be into an empty space, but it is forcibly absorbed, so that it will rise to a height considerably above its former level. This force is molecular, and is the same that we witness in the phenomena presented by the capillary tube, which affords us the simplest case of the insinuation of a liquid into a porous body. This force alone cannot, however, cause the liquid to pass entirely through the body. If a capillary tube, capable of raising water to the height of six inches, be depressed, so that one inch only be above the surface, the water will rise to the top of the tube, but no part of it will escape. Even if the tube be inserted horizontally into the side of a vessel containing water, the water will only pass to the end of the tube. The same thing occurs when a liquid is placed in contact with one side of a porous membrane: it enters the pores, passes to the opposite side, and is there arrested. But if this membrane communicates with a second vessel containing a different liquid—as a saline solution, capable of mixing with the first, and affected to a different degree by the capillary attraction—then a new phenomenon will be presented. It will be found that both liquids enter the pores, and pass through to the opposite side. They will not, however, be carried through with the same force; that which has the greatest capillary ascension,—that is, which will rise the highest in a capillary tube,—will pass through in the greatest quantity, and cause an accumulation of liquid in the opposite side.

The facts and arguments, adduced by Dr. Mitchell, clearly exhibit, that imbibition and transudation are dependent upon the penetrativeness of the liquid, and the penetrability of the membrane: that if two liquids, of different rates of penetrativeness, be placed on opposite sides of an animal membrane—"they will in time present the greater accumulation on the side of the less penetrant liquid, whether more or less dense; but will finally, thoroughly, and uniformly mix on both sides; and at length, if any pressure exist on either side, yield to that and pass to the other side."

A portion of the communication of Dr. Mitchell relates to an analogous subject, to which, as M. Magendie has observed, little or no attention has been paid by physiologists—the *permeability of membranes by gases.* "The laminæ," Magendie remarks, "of which membranes are constituted, are so arranged that the gases can penetrate them, as it were, without obstacle. If we take a bladder, and fill it with pure hydrogen gas, and afterwards leave it in contact with atmospheric air, in a very short time the hydrogen will have lost its purity, and will be mixed with the atmospheric air, which has penetrated the bladder. This phenomenon is the more rapid in proportion as the membrane is thinner and less dense. It presides over one of the most important acts of life—respiration—and it continues after death."

Dr. Mitchell is the first individual, who directed his observation to the relative penetrativeness of different gases. This he was enabled to discriminate by the following satisfactory experiment, which we give in his own words: "Having constructed a syphon of glass, with one limb three inches long, and the other ten or twelve inches, the open end of the short leg was enlarged and formed into the shape of a funnel, over which, finally, was firmly tied a piece of thin gum elastic. By inverting this syphon, and pouring into its longer limb some clean mercury, a portion of common air was shut up in the short leg, and was in communication with the membrane. Over this end, in the mercurial trough, was placed the vessel containing the gas to be tried, and its velocity of penetration measured by the time occupied in elevating to a given degree the mercurial column in the other limb. Having thus compared the gases with common air, and subsequently, by the same instrument, and in bottles, with each other, I was able to arrange the following gases according to their relative facility of transmission, beginning with the most powerful: Ammonia, sulphuretted hydrogen, cyanogen, carbonic acid, nitrous oxide, arsenuretted hydrogen, olefiant gas, hydrogen, oxygen, carbonic oxide, and nitrogen."

He found that *ammonia* transmitted in one minute as much in volume as *sulphuretted hydrogen* did in two minutes and a half; *cyanogen*, in three minutes and a quarter; *carbonic acid*, in five minutes and a half; *nitrous oxide*, in six minutes and a half; *arsenuretted hydrogen*, in twenty-seven minutes and a half; *olefiant gas*, in twenty-eight minutes; *hydrogen*, in thirty-seven minutes and a half;

oxygen, in one hour and fifty-three minutes; and *carbonic oxide*, in two hours and forty minutes.

It was found, too, that up to a pressure of sixty-three inches of mercury, equal to more than the weight of two atmospheres, the penetrative action was capable of conveying the gases—the subjects of the experiment—into the short leg through the gum elastic membrane. Hence the degree of force exerted in the penetration is considerable.

The experiments were all repeated with animal membranes, such as dried bladder and gold-beater's skin, moistened so as to resemble the natural state. The same results, and in the same order, followed as with the gum elastic. The more fresh the membrane, the more speedy and extensive was the effect; and in living animals the transmission was very rapid.

To these experiments we shall have frequent occasion to refer in the course of this work.

All these different properties of animal solids are independent of the vital properties. They continue for some time after the total extinction of life in all its functions, and appear to be connected either with the physical arrangement of molecules, the chemical composition of the substance in which they reside, or with peculiar properties in the body that is made to act on the tissue. They do not, indeed, seem to be affected, until the progress of decomposition has become sensible. Hence, many of these agencies have been termed collectively, by Haller, the *vis mortua*.

OF THE FUNCTIONS OF MAN.

Having described the intimate structure of the tissues, we pass to the consideration of the functions, the character of each of which is,—that it fulfils a special and distinct office in the economy, for which it has an organ or an instrument, or an evident apparatus of organs.

Physiologists have not, however, agreed on the number of distinct offices which are so performed; and hence the difference, in the number and classification of the functions, that prevails amongst them.

The oldest division is into the *vital, natural, and animal;* the *vital functions* including those of such importance as not to admit of interruption, such as circulation, respiration, and the functions of the brain and spinal marrow; the *natural functions* including those that effect nutrition, as digestion, absorption and secretion; and the *animal,* those possessed exclusively by animals, as sensation, locomotion, and voice. This classification is the basis of that which generally prevails at the present day.

The character of this work will not admit of a detail of every classification which has been proposed by the physiologist; that of Bichat, however, has occupied so large a space in the public eye, that it cannot well be passed over. It is the one followed by M. Richerand, and by many modern writers.

Bichat includes all the functions under two heads, according as they work to one or other of two ends,—*functions of nutrition* or *life of the individual,* and *functions of reproduction,* or *life of the species.* Nutrition requires that the being shall establish relations around him to obtain the materials of which he may stand in need; and, in animals, the functions, which establish such relations, are under the volition and perception of the being. Hence they are divided into two sorts;—those, that commence or precede nutrition, consist of external relations, are dependent upon the will, and executed with consciousness; and those that are carried on within the body, spontaneously, and without consciousness. Bichat adopted this basis, and to the first aggregate of functions he applied the term *animal life,* because it comprised those that characterize animality; the latter he called *organic life,* because the functions comprised under it are common to every organized body. *Animal life* included sensation, motion and expression; *organic life,* digestion, absorption, respiration, circulation, nutrition, secretion, &c.

In animal life, Bichat recognized two series of actions, opposed to each other, the one proceeding from without and terminating in the brain, or passing from circumference to centre, and comprising the external senses; the other, commencing in the brain and acting on external bodies, or proceeding from centre to circumference, and including the internal senses, locomotion, and voice. The brain, in which one series of actions terminates and the other begins, he considered the centre of animal life.

In organic life he likewise recognized two series of actions; the one proceeding from without to within, and effecting composition; the other passing from within to without, and effecting decomposition. In the former, he included digestion; absorption; respiration, by which the blood is formed; the circulation, by which the blood is conveyed to different parts, and the functions of nutrition, and calorification. In the latter, that absorption, which takes up parts from the body; the circulation, which conducts those parts or materials to the secretory or depuratory organs; and the secretions, which separate them from the economy.

In this kind of life, the circulation is common to the two movements of composition and decomposition; and, as the heart is the great organ of the circulation, he considered it the centre of organic life; and, lastly, as the lungs are united both with animal life, in the reception of air, and with organic life, as the organs of sanguification, Bichat regarded those organs as the bond of union between the two lives. Generation constituted the *life of the species.*

The classification, adopted in this work, will be that embraced by Magendie; and, after him, by Adelon, who has written one of the best systems of human physiology which we possess.

The FIRST CLASS, or *functions of relation, or animal functions*, includes those that establish our connexion with the bodies surrounding us; the *sensations, voluntary motions* and *expressions*. The SECOND CLASS, or *functions of nutrition*, comprises *digestion, absorption, respiration, circulation, nutrition, calorification*, and *secretion*, and the THIRD CLASS, the *functions of reproduction,—generation.*

Table of the Functions.

FUNCTIONS.	I. *Animal* or *of Relation.*	1. Sensibility. 2. Muscular motion. 3. Expressions or language
	II. *Nutritive.*	4. Digestion. 5. Absorption. 6. Respiration. 7. Circulation. 8. Nutrition. 9. Calorification. 10. Secretion.
	III. *Reproductive.*	11. Generation.

In studying each of these functions, we shall first of all describe the organ or apparatus concerned in its production; but, so far only as is necessary in a physiological point of view,—the further developement, and the application of such developement to other departments of medical science, not immediately concerning the physiologist,—and shall next detail what has been called the *mechanism* of the function, or the mode in which it is effected.

In many cases it will happen, that some external agent is concerned in its production, as *light* in vision; *sound* in audition; *odours* in olfaction; *tastes* in gustation, &c. The properties of these will, in all instances, be detailed in a brief manner, but so far only as is necessary for our immediate purpose.

The difficulty of observing actions, that are carried on by the very molecules of which the organs are composed, has given rise to many hypothetical speculations, some of which are sufficiently ingenious; others too fanciful to be indulged, by the reflecting, for a moment; and, as might be expected, the number of these fantasies generally bears a direct proportion to the difficulty and obscurity of the subject. It will not be proper to pass over the most prominent of these, but they will not be dwelt upon, whilst the results of direct observation and experiment will be fully detailed; and, where differences prevail amongst observers, such differences will be attempted to be reconciled, where practicable.

The functions, executed by different organs of the body, can be deduced by direct observation, although the minute and molecular action, by which they are accomplished in the very tissue of the organ, may not admit of detection. We see, for example, blood proceeding to the liver, and the vessels that convey it, ramifying in the texture of the viscus, and becoming so minute as to escape vision, even when aided by a powerful microscope. We find, again, other vessels becoming perceptible, gradually augmenting in size, and ultimately terminating in a larger duct, that opens into the small intestine. If we examine each of these orders of vessels in their most minute appreciable ramifications, we discover, in the one, always blood, and, in the other, always a very different fluid,—bile. We are hence led to the conclusion, that in the intimate tissue of the liver, and in some part, communicating directly or indirectly with both these orders of vessels, bile is separated from the blood; in other words, that the liver is the organ of the biliary secretion. On the other hand, functions exist, which cannot be so demonstratively referred to an organ. We have every *reason* for believing, that the brain is the exclusive organ of the mental and moral manifestations; but, as few opportunities occur for seeing it in action, and as the operation is too molecular to admit of direct observation when we do see it, we are compelled to connect the organ and function by a process of reasoning only; yet we shall find, that the results, at which we arrive in this manner, are by no means the least satisfactory.

The forces that preside over the various functions are either *general*,—that is, physical or chemical; or *special*,—that is, organic or vital. Some of the organs afford us examples of purely physical instruments. We have, for instance, in the eye, an eye-glass, if we may so call it, of admirable construction; in the organ of voice, an instrument of music; in the ear, one of acoustics. The circulation is carried on through an ingenious hydraulic apparatus, whilst station and progression involve various laws of mechanics. In many of the functions, again, we have examples of chemical agency, whilst all those, in which innervation is concerned, we are incapable of explaining on any physical or chemical principle, and are constrained to esteem *vital*.

CLASS I.

ANIMAL FUNCTIONS, OR FUNCTIONS OF RELATION.

The functions of relation consist, *first*, of sensibility, and *secondly*, of muscular motion, including expression or language. All these actions are subject to intermission, constituting *sleep;* a condition which has, consequently, by many physiologists, been investigated under this head; but as the functions of reproduction are also influenced by the same condition, the consideration of sleep will be deferred until the third class of functions has engaged attention.

OF SENSIBILITY, OR THE FUNCTION OF THE SENSATIONS.

Sensibility is the function by which an animal experiences feeling, or has the perception of an impression. In its general acceptation, it means the property possessed by living parts of receiving impressions, whether the being, exercising the property, has consciousness of it or not. To the former of these cases—in which there is consciousness—Bichat gave the epithet *animal;* to the second, *organic;* the latter being common to animals and vegetables, and presiding over the *organic* functions of nutrition, absorption, exhalation, secretion, &c.; the former existing only in animals, and presiding over the sensations, internal as well as external.

It is to *animal sensibility*, that our attention will have to be directed.

Pursuing the plan, already laid down, we shall commence the study of this interesting and elevated function, by pointing out, as far as may be necessary, the apparatus that effects it, comprising the whole of the *nervous system.*

Of the Nervous system.

Under the name *nervous system* anatomists include all those organs, that are composed of the nervous or pulpy tissue. In man, it is constituted of three portions; *first*, of what has been called the *cerebro-spinal axis*, a central part having the form of a long cord, expanded at its superior extremity, and contained within the cavities of the cranium and spine; *secondly*, of cords, called *nerves*, in number thirty-nine pairs, according to some,—forty-two according to others,—passing off laterally from the cerebro-spinal axis to every part of the body; and, lastly, of a nervous cord, situated on each side of the spine, from the head to the pelvis, forming *ganglia* opposite each vertebral foramen, and called the *great sympathetic nerve.*

1. *Of the encephalon.*—Under this term are included the contents of the cranium, namely, the *cerebrum* or *brain proper;* the *cerebel-*

lum or *little brain;* and the *medulla oblongata.* These various parts have been included by some under the name *brain.* When we look at a section of the encephalon, and at the three organs in their natural position, we find that there are many distinct parts, and appearances of numerous and separate organs. So various, indeed, are the prominences and depressions observable on the dissection of the brain, that it is generally esteemed one of the most difficult subjects of anatomy. Yet, owing to the attention that has been paid to it in all ages, it is now one of the structures best understood by the anatomist.

This complicated organ affords us a striking illustration of the truth, that the most accurate anatomical knowledge will not necessarily teach the function.

The elevated actions, which the encephalon has to execute, have attracted a large share of the attention of the physiologist,—too often, however, without any satisfactory result; yet it may, we think, be safely asserted, that we have become better instructed regarding the uses of particular parts of the brain, within the last few years, than during the whole of the century preceding.

The encephalon being of extremely delicate organization, and its functions easily deranged, it was necessary that it should be securely lodged, and protected from injuries. Accordingly, it is placed in a round, bony case, and, by an admirable mechanism, is defended against damage from surrounding bodies.

Amongst these guardian agents or *tutamina cerebri* must be reckoned;—the hair of the head, the skin, muscles, pericranium, bones of the skull, the diploë separating the two tables of which the bones are composed, and the dura mater.

It is not an easy matter to assign probable uses to the hair on various parts of the body. On the head, its function seems more readily appropriable. It deadens the concussion, which the brain would experience from the infliction of heavy blows, and prevents the skin of the scalp from being injured by the attrition of bodies. In military service, the former of these uses has been taken advantage of, and an arrangement somewhat similar to that which exists naturally on the head, has been adopted with regard to the helmet. The metallic substance, of which the ancient and modern helmets are formed, is readily thrown into vibration; which vibration, being communicated to the brain, might, on the receipt of heavy blows, derange its functions more even than a wound inflicted by a sharp instrument. To obviate this, in some measure, the helmet has been covered with horse hair. This arrangement prevailed in the helmet worn by the Roman soldier.

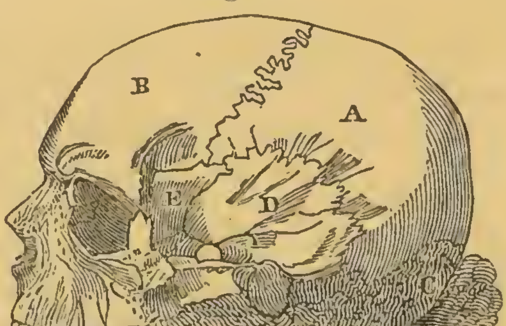
There can be no doubt, likewise, that being bad conductors of caloric, and forming a kind of felt which intercepts the air, the hairs may tend to preserve the head of a more uniform temperature. They are, moreover, covered with an oily matter, which prevents them from imbibing moisture, and causes them to dry speedily. Another use, ascribed to them by Magendie, is somewhat more hypothetical;—that being bad conductors of electricity, they may put the head in a state of insulation, so that the brain may be less affected by the electric fluid!

It is unnecessary to explain in what manner the different layers, of which the scalp is composed, the cellular membrane beneath, the panniculus carnosus or occipito-frontalis muscle, and the pericranium covering the bone, act the parts of tutamina. The most important of these protectors is the bony case itself. In the short treatise on *Animal Mechanics*, contained in the *Library of Useful Knowledge*, and written by one of the most distinguished physiologists of the present day, Sir Charles Bell, we have some beautiful illustrations of the wisdom of God, as displayed in the mechanism of man, and in that of the skull in particular and although some of his remarks may be liable to the censures which have been passed upon them by Dr. Arnott, the greater part are admirably adapted for the contemplated object. It is impossible, indeed, for the uninitiated to rise from the perusal of his interesting essay, without being ready to exclaim with the poet, "how wonderful, how complicate is man! how passing wonder HE that made him such!"

Sir Charles attempts to prove, that the best illustration of the form of the head is the dome; whilst Dr. Arnott considers it to be "the arch of a cask or barrel, egg-shell, or cocoa-nut, &c. in which the tenacity of the material is many times greater than necessary to resist the influence of gravity, and comes in aid, therefore, of the curve, to resist forces of other kinds approaching in all directions as in falls, blows, unequal pressures," &c. The remarks of Dr. Arnott on this subject are just; and it is owing to this form of the cranium, that any blow received upon one part of the skull is rapidly distributed to every other; and that a heavy blow, inflicted on the forehead or vertex, may cause a fracture, not in the parts struck, but in the occipital or sphenoidal bones.

The skull does not consist of one bone, but of many. These are joined together by *sutures*,—so called from the bones seeming as if they were stitched together. Each bone consists likewise of two tables; an external, fibrous and tough, and an internal, of a harder character and more brittle, hence called *tabula vitreà*. These two tables are separated from each other by a cellular or cancellated structure, called *diploë*. On examining the mode in which the tables form a junction with each other at the sutures, we find additional evidences of design exhibited. The edges of the outer table are serrated, and so arranged as to be accurately dovetailed into each other; the tough

Fig. 8.



Skull.

A. The *parietal* bone.
B. The *frontal* bone.
C. The *occipital* bone.
D. The *temporal* bone.
E. The *sphenoid* bone.

fibrous texture of the external plate being well adapted for such a junction. On the other hand, the tabula vitrea, which, on account

Fig. 9.

Disarticulated bones of the skull.

1. The frontal bone. (The central division between the two bones does not exist in the adult.) —2. Parietal bone —3. Occipital bone.—4. Temporal bone.—5. Ethmoid bone.—6. Sphenoid bone.—7. Superior maxillary bone.—8. Cheek bone.—9. Palate bone.—10. Lachrymal bone.—11. Nasal bone.—12. Inferior maxillary bone.

of its greater hardness, would be liable to fracture, to chip off, is merely united with its fellow at the suture, by what is called *harmony:* the tabulæ are, in other words, merely placed in contact.

The precise object of these sutures is not apparent. In the mode in which ossification takes place in the bones of the skull, the radii from different ossific points must necessarily meet, in the progress of ossification. This has, by many, been esteemed the cause of the sutures, but the explanation is insufficient. However it may be, the kind of junction affords an example of beautiful adaptation. During the fœtal state, the sutures do not exist. They are fully formed in youth, are distinct in the adult age, but, in after periods of life, become entirely obliterated, the bone then forming a solid spheroid. It does not seem, however, that after the sutures are established, any displacement of the bones can take place; and observation has shown, that they do not possess much, if any, effect in putting a limit to fractures. In all cases of severe blows, the skull appears to resist as if it were constituted of but one piece.

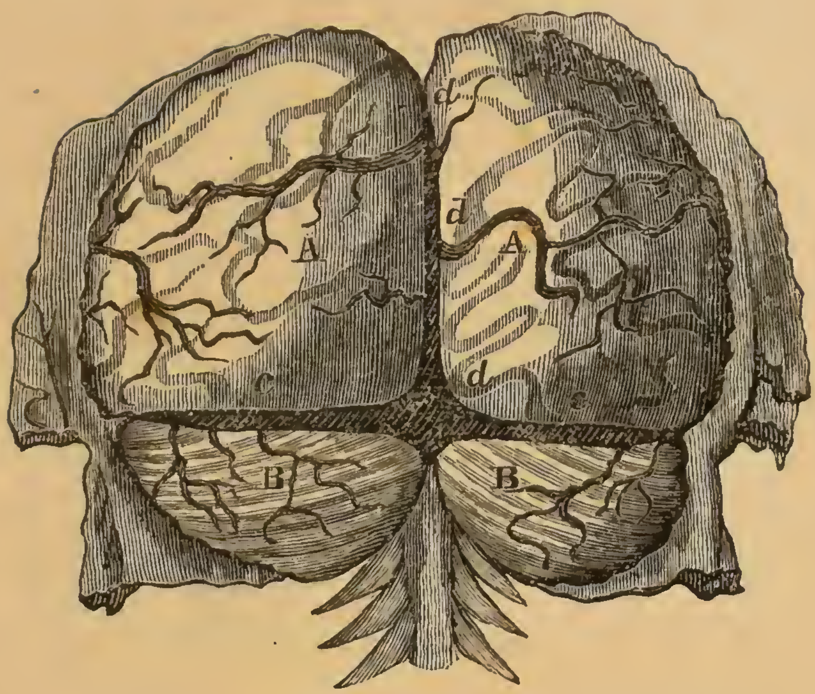
But the separation of the skull into distinct bones, which have a membranous union, is of striking advantage to the fœtus in parturition. It enables the bones to overlap each other; and, in this way, to occupy a much smaller space than if ossification had united them, as in after life. It has, indeed, been imagined by some, that there is this advantage in the pressure made on the brain by the investing bones—that the fœtus does not suffer from the violent efforts made to extrude the child; but that, during the passage through the pelvis, it is in a state of fortunate insensibility. That pressure suddenly exerted upon the brain is attended with these effects, is well known to the pathologist. It is, indeed, the great principle to be borne in mind in the management of apoplexy, fracture of the skull, &c.

The uses of the *diploë*, which separates the two tables of the skull, are not equivocal. Composed of a cancellated structure, it is well adapted to deaden the force of blows, and as it forms, at the same time, a bond of union and of separation, a fracture might be inflicted upon the outer table of the skull, and yet be prevented from extending to the tabula vitrea. Such cases have occurred, but they are rare. It will generally happen, that a blow, intended to cause rious bodily injury, will be sufficient to break through both tables or neither.

Lastly, the *dura mater*, which has been reckoned as one of the tutamina cerebri, lines the skull and constitutes a kind of internal periosteum to it. It may also be inservient to useful purposes, by deadening the vibrations, into which the head may be thrown by sudden concussions; as the vibrations of a bell are arrested by lining it with some soft material. It is chiefly, however, to protect the brain against itself, that we have the arrangement, which prevails in the dura mater.

The cerebrum, as well as the cerebellum, consists of two hemispheres; and its posterior part is situated immediately above the cerebellum. It is obvious, then, that without some protection, the hemisphere of one side would press upon its fellow, when the head is inclined to the opposite side; and that the posterior lobes of the brain would weigh upon the cerebellum in the erect attitude.

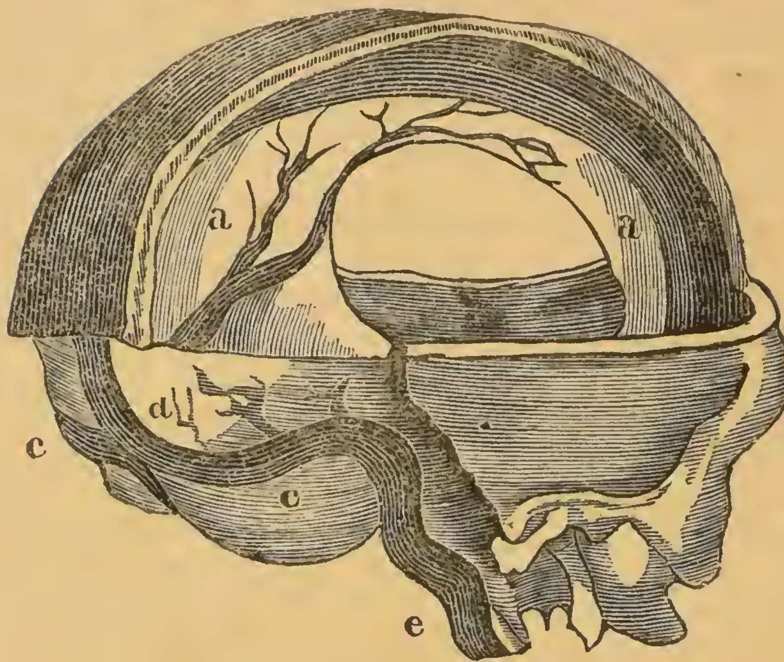
Fig. 10.



Posterior view of the encephalon.

Fig. 10, is a posterior view of the cerebrum and cerebellum; the cranium and dura mater being removed. A A are the *hemispheres*, separated from each other by the *falx cerebri*, in the upper margin of which is the *superior longitudinal sinus*, *d d*. The falx passes between the hemispheres in the mode exhibited at a a, Fig. 11.—c c, Fig. 10, is the situation of the *tentorium cerebello super-extensum*, which passes horizontally forwards, so as to support the posterior lobes of the brain, and prevent them from pressing injuriously on the *cerebellum*, B B. A process of the dura mater passes also between the hemispheres of the cerebellum, B B. Independently of the protection afforded to the encephalon, the dura mater lodges the great sinuses into which the veins discharge their blood. These different sinuses empty themselves into the *torcular Herophili* or *confluence of the sinuses* at d (Fig. 10 & 11), and ultimately proceed in the direction c c, constituting the *lateral sinuses*, which pass through the temporal bone, and form the *internal jugular veins*, one of which is represented at e, Fig. 11.

Fig. 11.



a a. The falx cerebri.
d. The torcular Herophili.
c c. The lateral sinuses.
e. The internal jugular vein.

The tutamina are not confined to the contents of the cranium. The spine appears to be, if possible, still better protected. In the skull, we see a firm, bony case; in the spine, a structure admitting considerable motion of the parts, without risk of pressure to the spinal marrow. Accordingly, the spine consists of numerous distinct bones or vertebræ, with fibro-cartilaginous—technically called *intervertebral*—substances, placed between each, so that, although the extent of motion between any two of these bones, may be small, the amount, when all are concerned, is considerable. The great use of this intervertebral substance is to prevent the jar, that would necessarily be communicated to the delicate parts, within the cavities of the spine and cranium, were the spine composed entirely of one bone. In falls from a height, upon the feet or breech, these elastic cushions are forcibly compressed; but they immediately return to their former condition, and deaden the force of the shock. In this they are aided by the curvatures of the spine, which give it the shape of the Italic *f*, and enable it to resist—in the same manner as a steel spring—any force acting upon it in a longitudinal direction. So well is the medulla spinalis protected by the strong bony processes, jutting out in various directions from the spine, that it is extremely rare to meet with lesions of the part; and it is comparatively of late years, that any *ex-professo* treatises have appeared on the subject.

Besides the protection afforded by the bony structure to the delicate medulla, Magendie has pointed out another, which he was the first to detect. The canal, formed by the dura mater around the spinal cord, is much larger than is necessary to contain that organ; but, during life, the whole of the intermediate space is filled with a serous fluid, which strongly distends the membrane, so that it will frequently spirt out to a distance of several inches, when a puncture is made in the membrane. To this fluid, he has given the epithet *cephalo-spinal;* and he conceives, that it may act as one of the tutamina of the marrow, (which is, as it were, suspended in the fluid,) and exert upon it the pressure necessary for the healthy performance of its functions.

Beneath the dura mater is situated a very delicate membrane, the *arachnoid*, belonging to the class of serous membranes. It surrounds the encephalon in every part, but is best seen at the base of the brain. Its chief use is to secrete a thin fluid, to lubricate the brain. This membrane enters into all the cavities of the organ, and in them fulfils a like function. When the fluid accumulates to a great extent, it constitutes the disease called *hydrocephalus chronicus.*

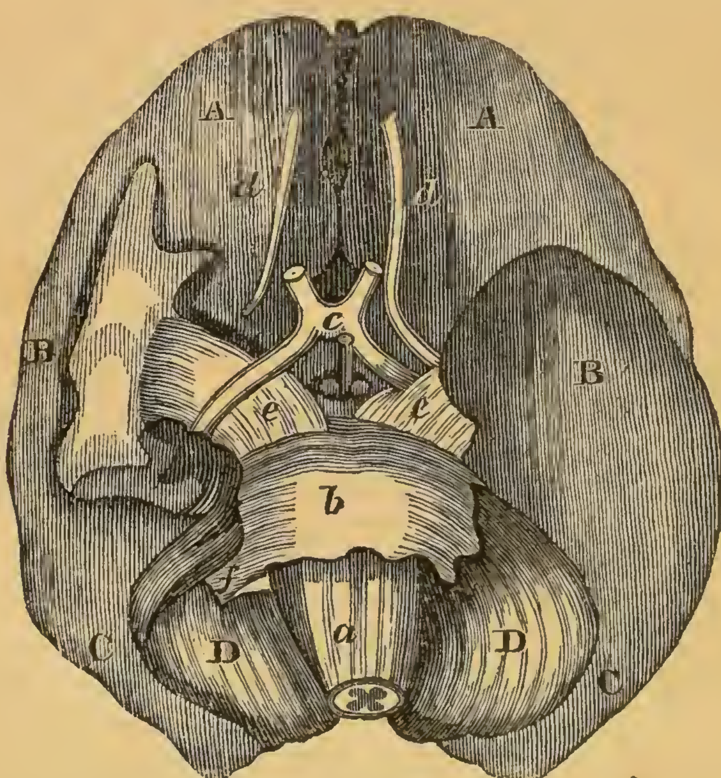
Anatomists usually describe a third tunic of the brain—the *pia mater.* As a distinct membrane this is not demonstrable. It is generally conceived to consist of the minute terminations of the cerebral arteries, and those of the corresponding veins, forming, at the surface of the brain, a vascular net-work, which passes into the cavities; and, in the ventricles, forms the *plexus choroides*, and *tela choroidea.* The dura and pia mater were so called, by the older anatomists, because they were conceived to be the origin of all the other membranes of the body.

The *cerebrum* or *brain proper* has the form of an oval, larger behind. On its outer surface are various undulating eminences, called *convolutions*, because they have been thought to resemble the folds of the intestines—separated from each other by depressions, called *anfractuosities.* (See Fig. 13.) In the brain of man, these convolutions are larger than in animals, and the anfractuosities deeper. In different brains, the number, size, and arrangement of these vary. They are not the same, indeed, in the same individual; those of the right hemisphere being disposed differently from those of the left.

The hemispheres, we have seen, are separated *above* by the falx cerebri: *below*, they are united by a white medullary commissure, the *corpus callosum*, *mésolobe* or *great commissure.* If we examine the brain at its base, we find that each hemisphere is divided into three lobes,—an *anterior*, which rests on the vault or roof of the orbit,—a *middle* or *temporal*, filling the middle and lateral parts of the base of the cranium, and separated from the former by a considerable depression, called the *fissure of Sylvius*,—and a *posterior*, which rests on the tentorium cerebelli. This part of the cerebrum is divided into two very distinct portions by the medulla oblongata. Anterior to it are the *crura cerebri* or *cerebral peduncles*,—by most anatomists considered to be a continuation of the anterior fasciculi which form the spinal marrow and medulla oblongata, and proceeding to form the hemispheres of the brain. Between the anterior extremities of the peduncles are two hemispherical projections, called *eminentiæ mamillares,* which are possessed by man exclusively, have the shape of a pea, and are formed of the white nervous tissue externally, of the gray within. Anterior to these again is the *infundibulum,* and a little farther forwards the *chiasma* of the optic nerves, or the part at which these nerves decussate.

Laterally, and at the inferior surface of the anterior lobes, is a groove or furrow, running from behind to before, and from without to within, in which the *olfactory nerve* is lodged. At the extremity of this furrow is a tubercle, which is trifling in man, but in certain animals is equal to the rest of the brain in bulk. From this the olfactory nerve has been conceived to arise. It is called the *olfactory tubercle* or *lobe.*

Fig. 12.



Base of the Brain.

A A. Anterior lobes of the brain—B B. Middle lobes— C C. Posterior lobes—D D. Cerebellum—*a.* Medulla oblongata—*b.* Pons Varolii—*c.* Chiasm of the optic nerves—*d.* Olfactory nerves—*e.* Crura cerebri—*f.* Crus cerebelli.

When we examine the interior of the brain, we find a number of parts to which the anatomist assigns distinct names. Of these, the following chiefly concern the physiologist. It has been already remarked, that the corpus callosum forms at once the bond of union and of separation between the two hemispheres. It is distinctly perceived, on separating these parts from each other, in the form of a long and broad white band. Beneath the corpus callosum is the *septum lucidum*, or median septum, which passes perpendicularly downwards, and separates from each other the two largest cavities of the brain—the *lateral ventricles.* It is formed of two laminæ, which leave a cavity between them, called the *fifth ventricle.* The *fornix* is placed horizontally below the last. It is of a triangular shape, and constitutes the upper paries of another cavity—the third ventricle. Beneath the fornix, and behind it, is the *pineal gland*, respecting which so much has been said, by Descartes and others, as the seat of the soul. Within it, is a small cavity; and, after six or seven years of age, it always contains some concretions. Again, anterior to the pineal gland, and immediately below the fornix, is another cavity—the *third ventricle.* Its bottom is very near the base of the brain, and is formed by the nervous layer, which unites the peduncles of the brain with the eminentiæ mamillares. (Fig. 12.) At the sides it has the thalami nervorum opticorum.

In the lateral ventricles, situated on each side of the corpus callosum, some parts exist which demand attention. In the upper or anterior half, commonly called the *anterior cornu*, and in the anterior part of this, two pyriform eminences are seen, of a brownish-gray colour, and which, owing to their being formed of an assemblage of alternate layers of white and gray substance, are called the *corpora striata.* Behind these, are two whitish medullary bodies, called *thalami nervorum opticorum*, which are situated before the corpora quadrigemina, and envelope the anterior extremities of the crura cerebri.

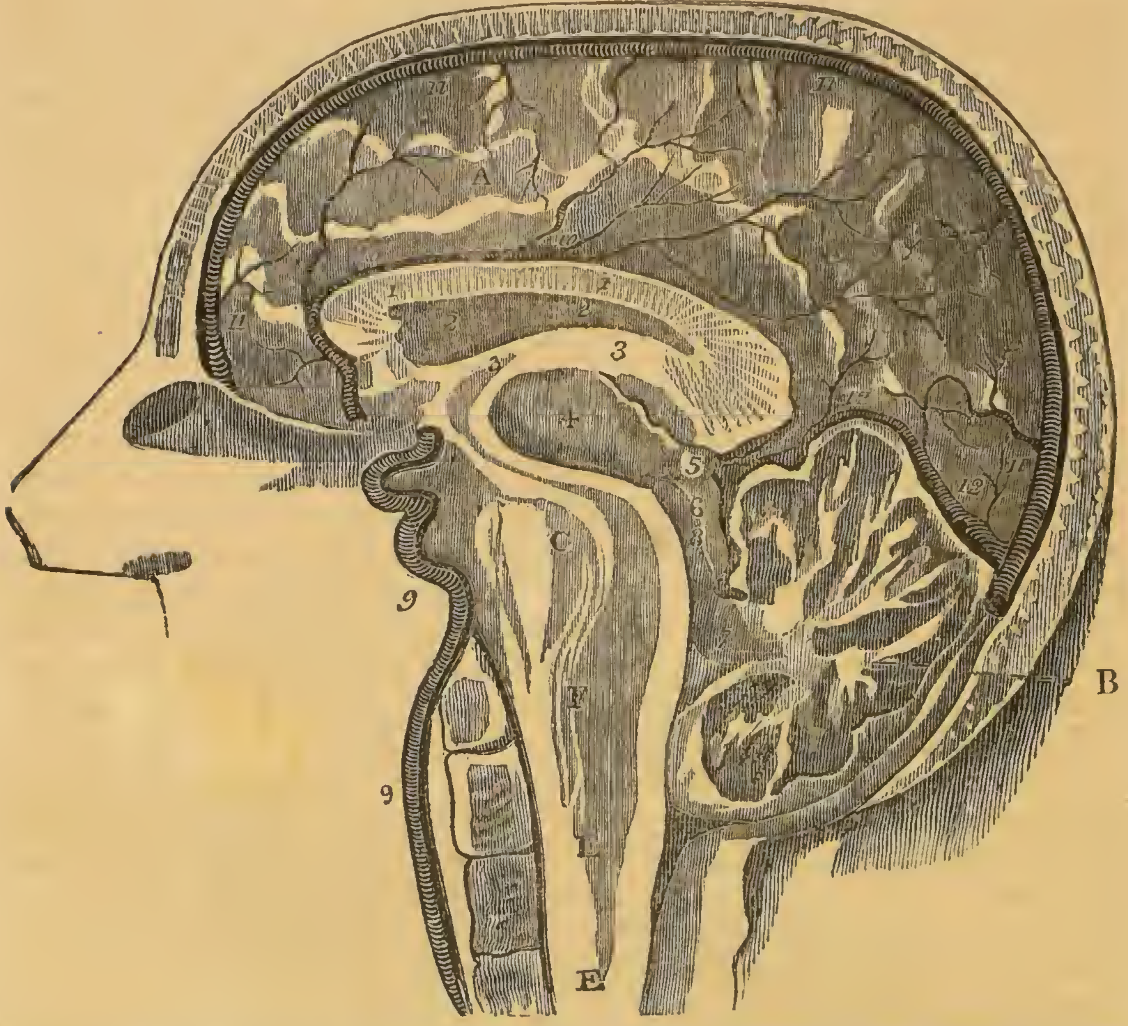
The *cerebellum* occupies the lower occipital fossæ, or the whole of the cavity of the cranium, which is beneath the tentorium cerebelli.

The size and weight of the cerebellum, like those of the brain, differ according to the individual, and the age of the subject under examination. We do not observe convolutions in it. It appears rather to consist of laminæ in superposition, separated from each other by a furrow. We shall see hereafter, that the number of cerebral convolutions has been esteemed, in some respects, to accord with the intellect of the individual; and Malacarne asserts, that he has observed a similar correspondence, as regards the number of the laminæ composing the cerebellum; that he found only three hundred and twenty-four in the cerebellum of an insane individual, whilst in others he had counted upwards of eight hundred.

From the medullary part of the cerebellum, two large white cords pass to the pons varolii, having the same disposition as the crura cerebri. They are the *crura cerebelli.*

Owing to the peculiar arrangement of the white and gray cerebral substances, when one of the hemispheres of the cerebellum is divided vertically, an arborescent appearance is presented,—the trunks of the arborizations being white, the surrounding substance gray. This appearance is called *arbor vitæ.* The part where all these arborizations meet, near the centre of the cerebellum, is called *corpus denticulatum vel rhomboidale.* Gall is of opinion, that this body has great agency in the production of the cerebellum. Lastly, the cerebellum covers the posterior part of the medulla oblongata, and forms with it a cavity, called the *fourth ventricle.*

Fig. 13.



1 1. Section of the corpus callosum—2 2. Lateral ventricle: the septum being removed—3 3. The fornix—4. Third ventricle—5. Pineal gland—6. Tubercula quadrigemina—7. Fourth ventricle—8. Iter a tertio ad quartum ventriculum—9 9. Internal carotid artery—10 10. Artery of the corpus callosum—11 11 11 11. Superior longitudinal sinus—12 12. Fourth sinus—A A. Cerebrum—B. Cerebellum—C. Pons varolii—E E. Medulla spinalis—F. Medulla oblongata.

The *medulla oblongata* is so called, because it is the continuation of the medulla spinalis in the cavity of the cranium. It is likewise termed *mésocephale,* from its being continuous with the spinal marrow in one direction, and sending towards the brain strong prolongations—the crura cerebri; and to the cerebellum similar prolongations—the crura cerebelli; so that it appears to be the bond of union between these various parts. In its lower portion, (Fig. 12, *a.*) it appears to be merely a continuation of the medulla spinalis, except that it is more expanded superiorly where it joins the pons varolii, *b.* This portion of the medulla oblongata is called, by some, the *tail of the medulla oblongata;* by others, the *rachidian bulb;* and by others again it is regarded as the whole medulla oblongata. Its lower surface, seen in the figure, rests on the basilary gutter of the occipital bone, and exhibits a groove, which divides the spinal cord into two portions. On each side of this furrow are two oblong eminences, the innermost of which is called *corpus pyramidale*, the outermost, *corpus olivare*, (Fig. 14.) which arise from the anterior column of the medulla spinalis, or are a continuation and subdivision of this column. On the posterior surface of the medulla oblongata, the posterior fasciculi separate to form the fourth ventricle; (Fig. 13, 7.) at the sides of this ventricle are the *corpora restiformia*, or *inferior peduncles* of the *cerebellum*, so called, because they seem to aid in the formation of that part of the encephalon; and, on the inner side of each corpus restiforme, is the small body—the *posterior pyramid*. Again, in addition to the corpora pyramidalia and olivaria—which derive their origin from, or are continuous with, the anterior fasciculi of the spinal cord, and are destined, according to some, to form the brain—and the corpora restiformia, which are continuations of the posterior fasciculi, and are destined to form the cerebellum, there exist, according to some anatomists, other fasciculi in the rachidian bulb. All these are interesting points of anatomy, but are not yet of much importance physiologically; if we except, perhaps, the views promulgated by Sir Charles Bell. He considers, that a column exists between the corpora olivaria and corpora restiformia, which extends below, through the whole spine, but above, does not proceed farther than the point where the rachidian bulb joins the tuber annulare, and that this column gives origin to a particular order of nerves—those inservient to respiration.

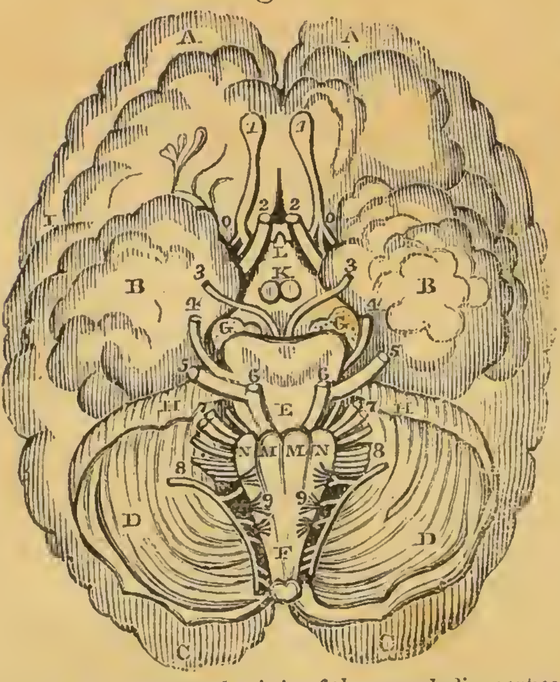
The anterior and upper half of the medulla oblongata bears the name *pons varolii*, *tuber annulare*, and *nodus cerebri*; and to this are attached, superiorly, the *corpora* or *tubercula quadrigemina*. In the very centre of the pons, the crura cerebri bury themselves; and are, by many, considered to decussate; and by others, to be prolongations of the anterior column of the spine. Sir C. Bell thinks, that the pons varolii stands in the same relation to the lateral portions of the cerebellum that the corpus callosum does to the cerebrum: that it is the great commissure of the cerebellum, uniting its lateral parts and associating the two organs.

2. The *spinal marrow* extends, in the vertebral canal, from the foramen magnum of the occipital bone, above, to the *cauda equina*, below. It is chiefly composed of medullary matter, but not entirely so. Within, the cineritious substance is ranged irregularly, but has a crucial form when a section is made of it. From the calamus scriptorius in the fourth ventricle, and the rima—formed by the corpora pyramidalia, before—two fissures extend downwards, which divide the spinal marrow into lateral portions. The two lateral portions are divided into an anterior and posterior, so that the cord has four distinct portions. By some, indeed, it is conceived to consist of three columns—an *anterior*, *posterior*, and *middle*.

The vertebral canal is connected by a strong ligamentous sheath, running down its whole length. The dura mater likewise envelopes the medulla at the occipital foramen, being firmly united to the ligaments, but farther down it constitutes a separate tube. The tunica arachnoidea from the brain adheres loosely to the cord, having the cephalo-spinal fluid within it, and the pia mater closely embraces it.

3. *Nerves.*—The nerves are cords of the same nervous substance as that, which composes the encephalon and spinal marrow, extending from these parts, and being distributed to the various organs of the body, many of them interlacing in their course, and forming *plexuses;* others having knots or *ganglions* upon them; and almost all vanishing in the parts to which they are distributed. The generality of English anatomists reckon thirty-nine pairs of nerves; the French, with more propriety, forty-two. Of these, nine, according to the English—twelve, according to the French—draw their origin from, or are connected with, the encephalon, are and hence called *encephalic* nerves; thirty from the medulla spinalis, and hence termed *spinal.* The encephalic nerves emerge from the cranium by means of foramina at its base. They are—proceeding from before to behind—the *first pair* or *olfactory,* distributed to the organ of smell; the *second pair* or *optic,* the expansion of which forms the retina; the *third pair, motores oculi,* or *common oculo-muscular,* which send filaments to most of the muscles of the eye; the *fourth pair, trochleares, pathetici,* or *internal oculo-muscular,* distributed to the greater oblique muscle of the eye; the *fifth pair, trifacial, trigemini,* or *symmetrical nerves of the head,* (Bell,) which send their branches to the eye, nose, and tongue; the *sixth pair, abducentes,* or *external oculo-muscular,* which are distributed to the abductor or rectus externus oculi; the *facial nerve, portio dura* of the seventh pair, *nervus communicans faciei,* or *respiratory nerve of the face,* distributed to the muscles of the face; the *acoustic nerve, auditory nerve,* or *portio mollis* of the seventh pair, which passes to the organ of hearing; the *eighth pair, pneumogastric, par vagum,* or *middle sympathetic,* which is dispersed particularly to the larynx, lungs, heart, and stomach; the *glosso-pharyngeal,* often considered as part of the last, and whose name indicates its distribution to the tongue and pharynx; the *great hypoglossus, ninth pair,* or *lingual nerve,* distributed to the tongue; and the spinal accessory of Wil-

Fig. 14.



Base of the brain and origin of the encephalic nerves.

A. Anterior lobes of the brain. B. Middle lobes. C. Posterior lobes. D. Cerebellum. E. Pons varolii. F. Medulla oblongata. G. Crura cerebri. H. Crura cerebelli. I. Fissure of Sylvius. K. Eminentiæ mamillares. L. Infundibulum. M. Corpora pyramidalia: N. Corpora olivaria. *o.* Roots of olfactory nerves. 1 1. Olfactory nerves. 2 2. Optic nerves. 3 3. Motores oculorum. 4 4. Pathetici. 5 5. Trigemini. 6 6. Abducentes. 7 7. Portio mollis and portio dura. 8. Glosso-pharyngeal, Par vagum, and Spinal Accessory. 9 9. Hypoglossal.

lis, which arises from the spinal cord in the cervical region, ascends into the cranium, and issues, by one of the foramina, to be distributed to the muscles of the neck. All these proceed from the medulla oblongata;—the brain and cerebellum not furnishing one.

The spinal nerves are thirty in number on each side. They make their exit by the intervertebral foramina, and are divided into eight *cervical*, twelve *dorsal*, five *lumbar*, and five or six *sacral*.

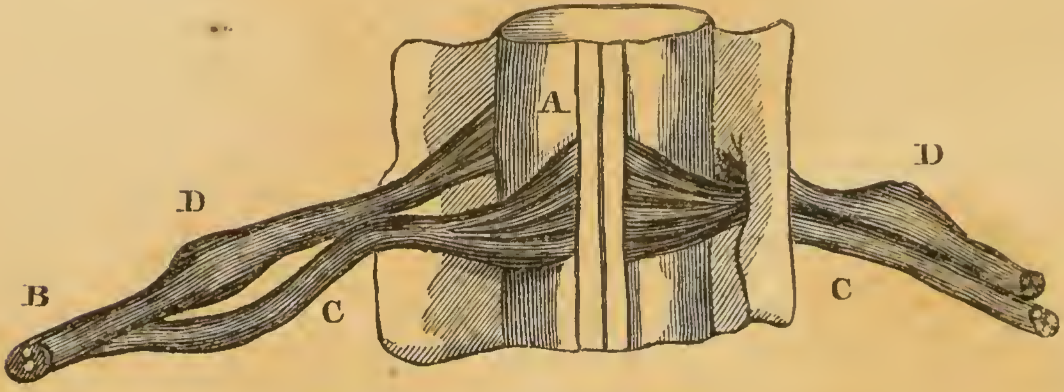
The encephalic nerves are irregular in their formation, and, with the exception of the fifth pair, originate from one root. Each of the spinal nerves arises from two fasciculi, the one anterior and the other posterior; these are separated from each other by the *ligamentum denticulare*; but they unite beyond this ligament, and, near the intervertebral foramina, present one of those knots, known under the name of *ganglions*, or *ganglia*, in the formation of which the posterior root is alone concerned.

When the nerves have made their exit from the cranium and spine, they proceed to the organs to which they have to be distributed, ramifying more and more, until they are ultimately lost sight of, even when vision is aided by a powerful microscope. Of the encephalic nerves, the olfactory, auditory, and acoustic—which are nerves of special sensibility—pass on to their destination, without communicating with any other nerve. The spinal nerves, at their exit from the intervertebral foramina, divide into two branches, an anterior and a posterior, one being sent to each aspect of the body. The anterior branches of the four superior cervical pairs form the *cervical plexus*, from which all the nerves of the neck arise; the four last cervical pairs, and the first dorsal, form the *brachial plexus*, whence proceed the nerves of the upper extremities, whilst the branches of the five lumbar nerves and the five sacral form the *lumbar* and *sciatic plexuses*, the former of which gives rise to the nerves distributed to the parts within the pelvis, and the second to those of the lower limbs. The anterior branches, moreover, at a little distance from the exit of the nerve from the vertebral canal, communicate with an important and unique portion of the nervous system, the *great sympathetic*.

Each nerve consists of numerous fasciculi, surrounded by cellular membrane; and, according to Reil, of an external envelope, called *neurilemma*, which, in the opinion of most anatomists, is nothing more than a cellular envelope, similar to that which surrounds the vessels and muscular fibres.

Until of late years, the nerves were universally divided, according to their origin, into *encephalic* and *spinal*; but, more recently, an anatomical division has been proposed, based upon the uses they appear to fulfil in the economy. For one of the most beautiful arrangements of this kind we are mainly indebted to Sir Charles Bell. We have already seen, that the encephalic nerves are connected with the encephalon by only one root, whilst the spinal nerves arise from two; the one connected with the anterior part of the spinal marrow, the other with the posterior. If these different roots be experimented on, we meet with results varying considerably from each other. If we divide, for example, the anterior root, the part, to which the nerve is distributed, is deprived of the power of motion, whilst if the posterior root be cut, the part is deprived of sensibility. We conclude, therefore, that each of the spinal nerves consists of filaments destined for both motion and sensibility; that the encephalic nerves, which have but one root, are destined for one of these exclusively, and that they are either nerves of motion or of sensation, according as their roots arise from the anterior or the posterior column of the medulla oblongata.

Fig. 15.



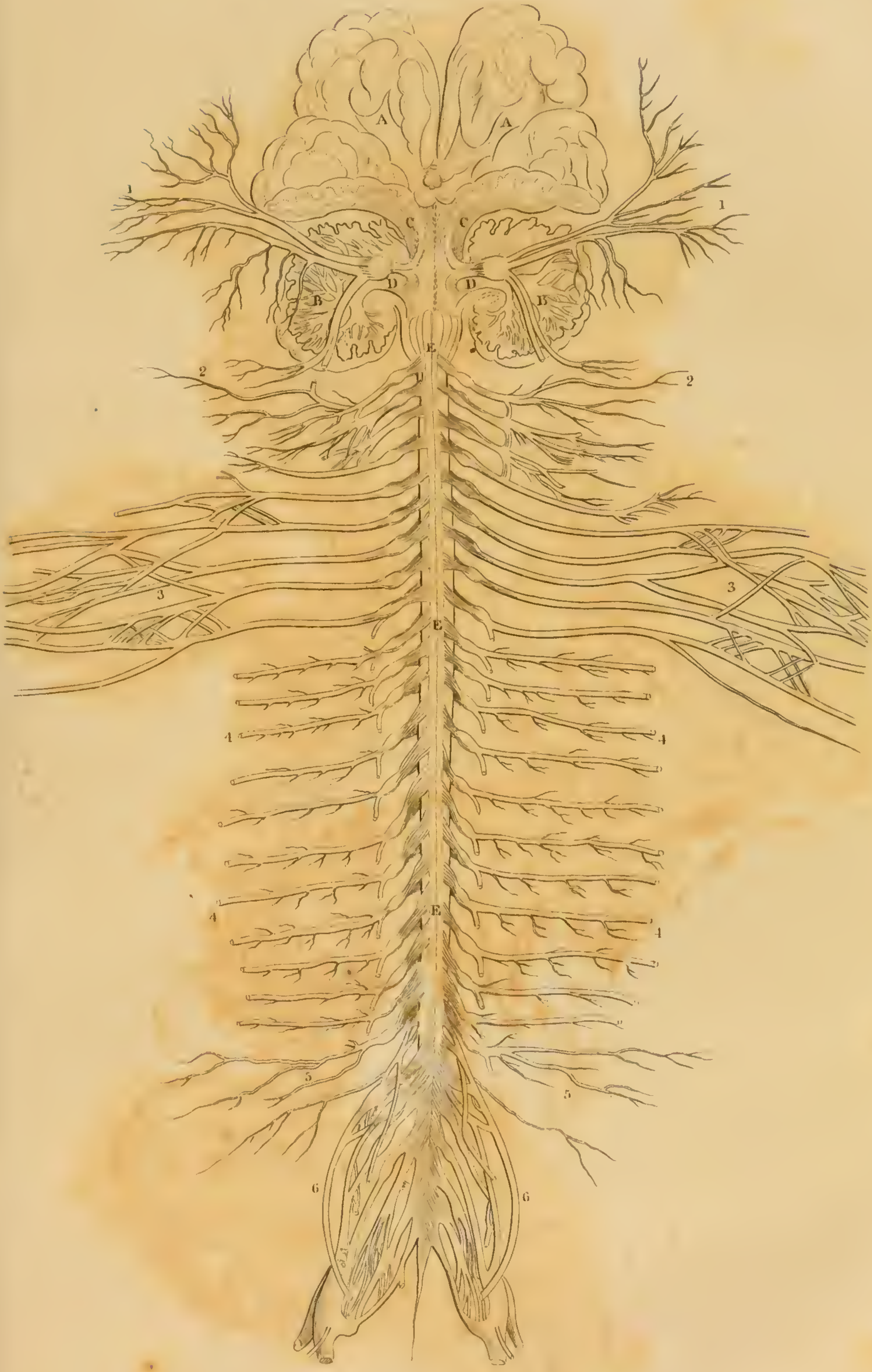
A. The spinal marrow, viewed in front.
B. A spinal nerve.
C. Anterior root of a spinal nerve.
D. Ganglion on the posterior root.

It has already been remarked, that the medulla oblongata, according to some anatomists, is composed of three fasciculi or columns on each side ; an *anterior*, *middle*, and *posterior* ; and it has been affirmed by Sir Charles Bell, that whilst the anterior column gives origin to nerves of motion, and the posterior to nerves of sensibility, the middle gives rise to a third species, having the function of presiding over the respiratory movements, and which Sir Charles accordingly calls the *respiratory nerves.* To this third order of nerves belong, —the *accessory nerve* of Willis or *superior respiratory*, the *vagus*, the *glosso-pharyngeal*, the *facial* called by him the *respiratory-nerve of the face*, the *phrenic* nerve, and another—having the same origin as the last—the *external respiratory.* Sir Charles Bell's views, if admitted, lead consequently, to the belief, that there are at least three sets of nerves, those destined for sensation, motion, and for a particular kind of motion—the respiratory; and that every nerve of motion communicates to the muscles, to which it is distributed, the power of aiding or taking part in motions of one kind or another, so that a muscle may be paralyzed, as regards certain movements, by the section of a nerve, and yet be capable of others of a different kind, by means of the nerves that are uninjured.

The accompanying plate exhibits the system of respiratory nerves, as given by Mr. Shaw, the son-in-law of Sir Charles Bell, who, some years ago, was prematurely snatched from existence, after having made numerous useful contributions to medical and surgical science.

SYSTEM OF RESPIRATORY NERVES.

REGULAR, OR SYMMETRICAL NERVES.



A is the cerebrum, B, the cerebellum, C C C, the spinal marrow, D, the tongue, E, the larynx, F, the lungs, G, the heart, H, the stomach, I, the diaphragm.

1 1 1. The par vagum, arising by a single set of roots and passing to the larynx, lungs, heart and stomach.

2. *Superior laryngeal branches* of the par vagum.

3. *Recurrent* or *inferior laryngeal branches* of the par vagum.

4. *Pulmonic plexus* of the par vagum.

5. *Cardiac plexus* of the par vagum.

6. *Gastric plexus* of the par vagum.

7. *Respiratory nerve* or *portia dura* passing to the muscles of the face, arising by a series of single roots.

8. Branches of the *glosso-pharyngeal.*

9. *Lingualis,* sending branches to the tongue and to the muscles on the fore part of the larynx.

10. Origins of the *superior external respiratory* or *spinal accessory.*

11. Branches of the last nerve proceeding to the muscles of the shoulder.

12 12 12. *Internal respiratory* or *phrenic* passing to the diaphragm.

The origins of this nerve are seen to be much higher up than they are generally described.

13. *Inferior external respiratory,* to the muscles on the side of the chest.

To Sir Charles Bell we are indebted for a further arrangement of the nerves, infinitely more natural and philosophical than the unmeaning numeration according to the system of Willis, and better adapted to facilitate the comprehension of this intricate portion of anatomy. It is, indeed, to the labours of Bell, Magendie, Meckel, and one or two others, that we owe the great improvements in our knowledge of the structure and functions of the nervous system.

According to Sir Charles Bell's arrangement, all the nerves of the body may be referred to two great classes—the *original, primitive,* or *symmetrical,*—and the *irregular* or *superadded.*

It has been already remarked, that a division of the spinal cord corresponds to the cerebrum and cerebellum. Now, every *regular nerve* has two roots, one from the anterior of these columns, and another from the posterior. Such are the fifth pair, the sub-occipital, the seven cervical, the twelve dorsal, the five lumbar, and the six sacral—*i. e.* thirty-two perfect, regular, or double nerves, including, to express it more briefly, all the spinal nerves, and one encephalic—the fifth pair. This fifth pair is found to arise from the encephalon by two roots, and to have a ganglion upon the posterior root. It is, accordingly classed with the spinal nerves, and, like them, conveys both motion and sensibility to the parts to which it is distributed.

These regular nerves are common to all animals, from the zoophyte to man. They run out laterally; or in other words, in a direction perpendicular to the longitudinal division of the body, and never take a course parallel to it.

The other class of nerves is called *irregular* or *superadded.* The different nervous cords, proceeding from it, are distinguished by a simple fasciculus or single root. All these nerves are simple in their origins, irregular in their distribution, and deficient in that symmetry, which characterizes the first class. They are superadded to the original class, and correspond to the number and complication of the superadded organs. Of these, there are the third, fourth, and sixth, distributed to the eye; the seventh, to the face; the ninth, to the tongue; the *glosso-pharyngeal,* to the pharynx; the *vagus,* to the larynx, heart, lungs, and stomach; the *phrenic,* to the diaphragm; the *spinal accessory,* to the muscles of the shoulders; and the *external respiratory,* to the outside of the chest.

The reason of the seeming confusion in this latter class is to be looked for in the complication of the superadded apparatus of respiration, and in the variety of offices it has to perform in the higher classes of animals. The plate exhibits, in one view, the nerves destined to move the muscles in all the varieties of respiration, speech, and facial expression.

In the plate of *regular* or *symmetrical nerves,* A is the cerebrum, B, the cerebellum, C C, the crura cerebri, D D, the crura cerebelli, E E E, the spinal marrow.

1 1. Branches of the fifth pair, arising from the union of the crura cerebri and crura cerebelli, and having a ganglion at the root. 2 2. Branches of the sub-occipital nerves, which have double origins and a ganglion. 3 3. Branches of the four inferior cervical nerves, and of the first dorsal, forming the axillary plexus. The origins of these nerves are similar to those of the fifth and of the sub-occipital. 4 4 4 4. Branches of the dorsal nerves, which also arise in the same manner. 5 5. The lumbar nerves. 6 6. The sacral nerves.

The fact, of the fifth pair of encephalic nerves having two roots, and essentially resembling the spinal nerves in arrangement and function, has drawn the attention of anatomists to the other encephalic nerves. The brain and cerebellum having been considered expansions of the anterior and posterior columns of the spinal marrow, and the cranium itself having, by some, been esteemed the uppermost vertebra of the body, differing from the others only in disposition, attempts have been made to reduce all the encephalic nerves to the same nature as the spinal and to show, that the great difference, in the case of the former, consists in the two roots not being united into a single trunk, and in each forming, consequently, a distinct pair of nerves. This is the opinion of Meckel, who accounts for the separation of the roots into distinct nerves by the large developement of the central mass of the nervous system within the cranium; and 2dly, by the existence, within the cranium, of particular organs for the senses, which keep the roots separate from each other.

The facts and reasoning, adduced by this distinguished anatomist on this subject, are, however, scarcely entitled to the epithet "ingenious," and are too indicative of the spirit of system and innovation to be accepted, were they even devoid of the weighty objections, that might be urged against them by the anatomist.

So much for the anatomy of the two great parts of the nervous system. We have still to consider a third, and by no means the least interesting.

4. *Great Sympathetic.*—This nerve, called also the *trisplanchnic*, *ganglionic*, and *great intercostal*, is constituted of a series of ganglions, joined to each other by a nervous trunk, and extending down the side of the spine, from the base of the cranium to the os coccygis or lowest bone of the spine. It communicates with each of the spinal nerves, and with several of the encephalic; and from the ganglions, formed by such communication, it sends off nerves, which accompany the arteries, and are distributed particularly to the organs of involuntary functions. At its upper part, it is situated in the carotid canal, where it appears under the form of a ganglionic plexus, two filaments of which proceed to join the sixth pair of encephalic nerves, and another to meet the vidian twig of the fifth pair. By means of the fifth pair, it communicates also with the ophthalmic ganglion, which Bichat considered to belong to it. On issuing from the carotid canal, the nerve passes downwards, along the side of the spine, to the sacrum, presenting a series of ganglions;—three in the neck, the *superior*, *middle*, and *inferior cervical*; twelve in the back, the *thoracic*; five in the loins, the *lumbar*; and three or four in the sacrum, the *sacral*. When it reaches the coccyx, it terminates by a small ganglion, called *coccygeal*, or by uniting with the great sympathetic of the opposite side.

The ganglions are of an irregular, but generally roundish, shape. They consist of nervous filaments, surrounded by a reddish gray, pulpy, albuminous, or gelatinous substance, which differs from the gray matter of the brain. Authors are by no means agreed, with regard to their uses. Willis, Haller, and others, considered them to be small brains for the secretion of the nervous fluid or animal spirits; an opinion, which has been embraced by Richerand and Cuvier, the latter of whom remarks, that the ganglia are larger and more numerous when the brain is deficient in size. Lancisi and Vicq d'Azyr regarded them as a kind of heart for the propulsion of these spirits, or as reservoirs for keeping them in deposit. Scarpa treats of them as synonymous with plexuses, being, according to him, plexuses with the filaments in close approximation, and the plexuses he regards as ganglions, whose filaments are more separated. He consequently believes, with many physiologists, that their office is to mix and unite various nervous filaments with each other. Dr. Wilson Philip thinks, that they are secondary sources of nervous influence, the specific office of which is to receive supplies of it from all parts of the brain and spinal marrow, and to transmit their united influence to the organs to which the nerves are distributed.

The most probable view, in our uncertainty, is that of Johnstone, Reil, and Bichat, that their use is to render the organs, which derive their nerves from them, independent of the will. The sympathetic is, indeed, the great system of involuntary nerves; and although connected with the brain by the branches of the fifth and sixth pairs of encephalic nerves, and with the spinal cord by the spinal nerves, it does not appear to be directly influenced by either; as the functions of the parts to which its ramifications are distributed, can continue for some time after both brain and spinal marrow have been separated; nay as in the case of the heart and intestines, after they have been removed from the body. Yet many discussions have been indulged regarding the origin of this important part of the nervous system; some assigning it to the brain, others to the spinal marrow, whilst others again, with more justice, esteem it a distinct nerve, communicating with the brain and spinal cord, but not originating from either; receiving, according to Broussais, by the cerebral nerves, the stimulant influence and applying it to movements, which are independent of the centre of perception. In like manner, he affirms, when irritation predominates in the viscera, it is conveyed by the ganglionic to the cerebral nerves, which transmit it to the brain. The point is still *sub lite*. Reil and Bichat, esteeming this nerve to be the great nervous centre of involuntary functions, have termed it the *organic nervous system*, in contradistinction to the *animal nervous system*, which presides over the animal functions.

The great sympathetic is esteemed to be the visceral nerve, *par excellence;* in other words, the nerve that supplies the different viscera with their nervous influence,—a part of its office as the nervous system of involuntary functions, for different offices of the viscera are carried on independently of volition. On examining the course of the great sympathetic, we find many filaments proceeding from the cervical and thoracic ganglions, interlacing and forming the cardiac plexus, from which the nerves of the heart and great vessels arise. The same thoracic ganglions furnish a branch to each intercostal artery. A nerve of the great sympathetic—called the *great splanchnic* or *visceral*—proceeding from some of the thoracic ganglions, passes through the pillars of the diaphragm into the abdomen, and terminates in the large plexus or ganglion, called the *semi-lunar*, and this, by uniting with its fellow of the opposite side, constitutes the still more extensive interlacing, the *solar plexus*. From this, numerous filaments proceed, which—by accompanying the coronaria ventriculi, hepatic, splenic, spermatic, renal, superior and inferior mesenteric, and hypogastric arteries—are distributed to the parts, which are supplied with blood by these arteries,—the stomach, liver, spleen, testes, kidneys, intestines, &c.

Weber, however, a German anatomist of distinction, who examined the great sympathetic in different animals, has afforded reason for believing that the splanchnic may not be the sole *visceral* nerve, but that the eighth pair, or par vagum may share in the function. He states, that the great sympathetic is less developed, the lower the animal; whilst the par vagum is more and more developed as we descend in the scale, and at length is the only visceral nerve in some of the mollusca.

According to the experiments of Flourens, the semilunar is the only ganglion, which exhibits any marked sensibility, and hence it has been considered as a sort of intervention to connect the viscera with the encephalon.

We are justified then, perhaps, in dividing the nerves with Lepelletier into five classes:—the *first* comprising the *nerves of special sensibility*—the olfactory, optic, lingual branch of the fifth pair, and the auditory:—the *second*, the *nerves of general sensibility*, the fifth pair; and the spinal nerves, through their posterior root:—the *third*, comprising the *voluntary motors*, the spinal nerves, by their anterior roots, the motores oculorum or common oculo-muscular, the external oculo-muscular, and the hypo-glossal:—the *fourth*, *instinctive motors*, involuntary, respiratory nerves of Sir Charles Bell, the pathetic, facial, glosso-pharyngeal, pneumogastric, and spinal accessory; and the *fifth*, *nerves of vital association* and *nutrition*—the filaments and plexuses of the ganglionic system.

All the parts that we have described as constituting the nervous system—brain, cerebellum, medulla spinalis, and nerves—are formed of the primary nervous fibre, the nature of which has been already described. The substance of which they are constituted is soft and pulpy, but the consistence varies in different portions, and, in the whole, at different ages. In the fœtus it is almost fluid; in youth, of greater firmness; and of still greater in the adult. This softness of structure in the encephalon of the fœtus is by no means inutile. It admits of the pressure, which takes place to a greater or less extent in all cases of parturition, whilst the head is passing through the pelvis, without the child sustaining any injury.

On examining, however, the consistence of different brains, it is necessary to inquire into the period that has elapsed since the death of the individual, as the brain loses its firmness by being kept, and ultimately becomes semi-fluid. It is likewise rendered fluid by disease, constituting the *ramollissement du cerveau*, or *mollescence of the brain*, to which the attention of pathologists has been directed of late years but without much important advantage to science.

When the encephalon is fresh, it has a faint, spermatic, and somewhat tenacious smell. This, according to Chaussier, has persisted for several years in brains that have been dried.

The substance, of which the nervous system is composed, has been subjected to analysis by Vauquelin, and found to contain, water, 80.00; white fatty matter, 4.53; red fatty matter, called *cerebrine*, 0.70; osmazome, 1.12; albumen, 7.00; phosphorus, 1.50;

sulphur, acid phosphates of potassa, lime, and magnesia, 5.15. In the spinal cord, there is more fatty matter, and less osmazome, albumen, and water. In the nerves, the albumen predominates, and the fatty matters are less in quantity. Researches by Lassaigne show, that water constitutes $\frac{7}{10}$ths of the nerves, and $\frac{8}{10}$ths of the brain; whilst the proportion of albumen, in the former, is $\frac{22}{100}$ths; in the latter, $\frac{7}{100}$ths.

Neither chemical analysis, nor inquiry into its minute structure by the aid of the microscope, has thrown light upon the wonderful functions executed by this elevated part of the economy.

To the naked eye, the nervous substance appears under two forms, the one of a gray colour and softer consistence, the other of a white colour and more compact. The former is called the *cortical, cineritious*, or *pulpy* substance; the latter, the *white, medullary*, or *fibrous*. The gray substance is not always, however, at the exterior, nor the medullary in the interior. In the medulla spinalis, their situation is the reverse of what it is in the brain. Ruysch considered, that the cineritious portion owes its colour to the blood-vessels which enter it; and, in the opinion, Haller and Adelon concur; but this is not probable, and it has by no means been demonstrated. The medullary portion has the appearance of being fibrous and it has been so regarded by Leeuenhoek, Vieussens, Steno, and by Gall and Spurzheim. Malpighi believed the gray cortical substance to be an assemblage of small follicles, intended to secrete the nervous fluid, and the white medullary substance to be composed of the excretory vessels of these follicles. Gall and Spurzheim, on the other hand, conjecture, that the use of the cineritious is to be the source or nourisher of the white fibres. The facts, on which they support their view, are, that the nerves appear to be enlarged when they pass through a mass of cineritious matter, and that masses of this substance are deposited in all parts of the spinal cord where it sends out nerves; but Tiedemann has remarked, that in the fœtus the medullary is developed before the cortical portion, and he conceives the use of the latter to be—to convey arterial blood, which may be needed by the medullary portion for the due execution of its functions.

Sir Charles Bell affirms, that he has found, at different times, all the internal parts of the brain diseased, without loss of sense, but that he has never seen disease general on the surface of the hemispheres, without derangement or oppression of mind during the patient's life; and hence he concludes, that the cineritious matter of the brain is the seat of the intellect, and the medullary of the subservient parts. A similar use has been ascribed to the cineritious portion, from pathological observations, by M M. Foville and Pinel Grandchamp.

This view would afford considerable support to the opinions of Gall, Spurzheim, and others, who consider the organs of the cerebral faculties to be constituted of expansions of the columns of the spinal marrow and medulla oblongata, and to terminate by radiating fibres on the periphery of the brain; as well as of Desmoulins, and those, who regard the convolutions as the seat of mind. We have, however, cases on record, which signally conflict with this view of the subject; cases in which the cortical substance has been destroyed and yet the moral and intellectual manifestations have been little, if at all, injured. Some years ago we dissected the brain of an individual of rank in the British army of India, the anterior lobes of which were in such a state, that neither medullary nor cortical portion could be distinguished, both one and the other appearing to be broken down into a semi-purulent, amorphous fluid; yet the intellectual faculties had been nearly unimpaired, although the morbid process must have been of considerable duration.

The encephalon affords us many striking instances of the different effects produced by sudden and by gradual interference with its functions. Whilst a depressed portion of bone or an extravasation of blood may suddenly give rise to the abolition of the faculties; the gradual compression, produced by a tumour, may scarcely interfere with any of its manifestations.

The circulation of blood in the encephalon requires mention. The arteries are four in number,—two *internal carotids*, and two *vertebrals;* to these may be added the *spinal artery* or *middle artery of the dura mater*,—the *arteria meningæa media.* The carotid arteries enter the head though the carotid canals, which open on each side of the sella turcica, or of the chiasma of the optic nerves. The vertebral arteries enter the head through the foramen magnum of the occipital bone; unite on the medulla oblongata to form the basilary artery, which passes forward along the middle of the pons varolii, and, at the anterior part of the pons, gives off lateral branches, which inosculate with corresponding branches of the carotids, and form a kind of circle at the base of the brain, which has been called the *circulus arteriosus* of Willis.

The passage of the blood-vessels is extremely tortuous, so that the blood does not enter the brain with great impetus; and the vessels become capillary before they penetrate the organ,—an arrangement of essential importance, when we regard the large amount of blood sent to the encephalon. This has been estimated as high as one-eighth of the whole fluid transmitted from the heart. The amount does not admit of accurate appreciation, but it is considerable. It must of course vary according to circumstances. In hypertrophy of the heart, the quantity sent is sometimes increased; as well as in ordinary cases of what are called *determinations* of blood to the head. Here, too large an amount is sent by the arterial vessels; but an equal accumulation may occur, if the return of the blood from the head, by means of the veins, be in any manner impeded,—as when we stoop, or compress the veins of the neck by a tight cravat, or by keeping the head turned for a length of time, &c., and then congestion or accumulation of blood may arise from very different causes.

The cerebral, like other arteries, are accompanied by branches of the great sympathetic.

The encephalic veins are disposed as already mentioned, terminating in *sinuses* formed by the dura mater, and conveying their blood to the heart by means of the lateral sinuses and internal jugulars. (See Fig. 11.)

No lymphatic vessels have been detected in the encephalon; yet, that absorbents exist there is proved by the dissection of apoplectic and paralytic individuals. In these cases, blood is sometimes effused within the brain, the red particles are gradually taken up, with a portion of the fibrinous part of the blood, leaving a cavity called an *apoplectic cell*, which is at the same time the evidence of previous extravasation and of subsequent absorption.

When the skull of the new-born infant, which at the fontanelles, consists of membrane only,—or the head of one who has received an injury, that exposes the brain,—is examined, two distinct movements are perceptible. The one, which is generally obscure, is synchronous with the pulsation of the heart and arteries; the other, much more apparent, is connected with respiration, the organ seeming to sink down at the time of inspiration, and to rise during expiration. This phenomenon is not confined to the brain, but exists likewise in the cerebellum and spinal marrow.

The motion of the encephalon, synchronous with that of the heart, admits, of easy explanation. It is owing to the pulsation of the circle of arteries at the base of the brain elevating the organ at each systole of the heart. The other movement is not so readily intelligible. It has been attributed to the resistance, experienced by the blood in its passage through the lungs during expiration, owing to which an accumulation of blood takes place in the right side of the heart: this extends to the veins and to the cerebral sinuses, and an augmentation of bulk is thus occasioned. We shall see hereafter, that one of the forces, conceived to propel the blood along the vessels, is atmospheric pressure. According to that view, the sinking down of the brain, during inspiration, is explicable:—the blood is rapidly drawn to the heart; the quantity in the veins is consequently diminished, and sinking down of the brain succeeds.

On dissection, we find that the encephalon fills the cavity of the cranium; during life, therefore, it must be pressed upon, more or less, by the blood in the vessels, and by the serous fluid exhaled by the arachnoid.

The spinal marrow, as we have seen, does not fill the vertebral canal, but the cephalo-spinal fluid exerts upon it the necessary pressure; added to which, the pia mater seems to press more upon this organ than upon the rest of the cerebro-spinal system. A certain degree of pressure appears, indeed, necessary for the due performance of its functions, and if this be either suddenly and considerably augmented, or diminished, derangement of function is the result. Magendie, however, asserts, that he has known animals, from which this fluid has been removed, survive without any sensible derangement of the nervous functions. It is this fluid, which is drawn off by the surgeon when he punctures in a case of spina bifida.

When the brain is examined in the living body, it exhibits properties, which, some years ago, it would have been esteemed the height of hardihood and of ignorance to ascribe to it. The opinion has universally prevailed, that all nerves are exquisitely sensible. We shall have many opportunities for remarking how far this sentiment is founded upon fact; but we are now prepared to assert, that even the encephalon itself,—the organ or organs in which perception takes place,—is insensible, in the common acceptation of the term; that is, we may prick, lacerate, cut, and even cauterize it, yet no painful impression will be produced. Experiment leaves no doubt regarding the truth of this, and we find the fact frequently confirmed in pathological cases.

Portions of brain may be discharged from a wound in the skull, and yet no pain be evidenced; and, in the last edition of his "Anatomy and Physiology," Sir C. Bell remarks, that he cannot resist stating, that on the morning on which he was writing, he had had his finger deep in the anterior lobes of the brain, when the patient, being at the time acutely sensible, and capable of expressing himself, complained only of the integument. A pistol ball had passed through the head, and having ascertained that it had penetrated the dura mater by forcing his finger into the wound, Sir Charles trepanned on the opposite side of the head, and extracted it.

By the experiments, instituted by Magendie and others, it has been shown, that an animal may live several days, and even weeks, after the whole of the hemisphere has been removed; nay, that in certain animals, as reptiles, no change is produced in their habitudes by such abstraction. They move about as if unhurt.

Injuries of the surface of the cerebellum exhibit, that it also is not sensible to that kind of irritation; but deeper wounds, and especially those that interest the peduncles, have singular results, to be explained hereafter.

The spinal chord is not exactly circumstanced in the same manner. Its sensibility is very exquisite on the posterior surface; much less on the anterior, and almost null at the centre. These columns as we have seen, have been esteemed the origins of the nerves of sensibility, motion, and respiration.

Considerable sensibility is also found within, and at the sides of, the fourth ventricle; but this diminishes as we proceed towards the anterior part of the medulla oblongata, and is very feeble in the tubercula quadrigemina of the mammalia.

It has been shown, that the spinal nerves, by means of their posterior roots, convey general sensibility to the parts to which they are distributed. But there are other nerves, which, like the brain, are themselves entirely devoid of general sensibility. This has given occasion to a distinction of nerves into those of *general* and of *special* sensibility. The nerves, which must be considered as insensible or devoid of general sensibility, are the optic, olfactory, and auditory. Each of these has, however, a *special sensibility*, and although they may exhibit no pain when irritated, they are capable of being impressed by appropriate stimuli, as by light, in the case of the optic nerve; by odours, in that of the olfactory; and by sound, in that of the auditory. Yet we shall find, that each of these nerves of special sensibility requires the influence of a nerve of general sensibility, the fifth pair. Many other nerves appear also devoid of sensibility, as the third, fourth, and fifth pairs; the portio dura of the seventh; the ninth pair of encephalic nerves; and, as has been shown, all the anterior roots of the spinal nerves.

The parts of the encephalon, concerned in muscular motion, will fall under consideration hereafter.

PHYSIOLOGY OF SENSIBILITY.

Sensibility we have defined to be—the function by which an animal experiences feeling, or has the perception of an impression. It includes two great sets of phenomena, the *sensations*, properly so called, and the *intellectual* and *moral manifestations*. These we shall consider in succession.

Of the Sensations.

A sensation is the perception of an impression made on some organ; or, in the language of Gall, it is the perception of any irritation whatever.

By the sensations we receive a knowledge of what is passing within or without the body; and, in this way, our notions or ideas of them are obtained. When these ideas are reflected upon, and compared with each other, we exert *thought* and *judgment;* and they can be recalled, with more or less vividness and accuracy, by the exercise of *memory*.

The sensations are numerous, but they may all be comprised in two divisions,—the *external* and the *internal*. Vision and audition afford us examples of the former, in which the impression, made upon the organ, is external to the part impressed. Hunger and thirst are instances of the latter, the cause here being internal, necessary, and depending upon influences seated in the economy itself. Let us endeavour to discover in what they resemble each other.

In the first place, every sensation, whatever may be its nature,—external or internal,—requires the intervention of the encephalon. The distant organ,—as the eye or ear,—may receive the impression, but it is not until this impression has been communicated to the encephalon, that sensation is effected. The proofs of this are easy and satisfactory. If we cut the nerve proceeding to any sensible part, if we put a ligature around it, or compress it in any manner, it matters not that the object, which ordinarily excites a sensible impression, be applied to the part, no sensation is experienced. Again, if the brain, the organ of perception, be prevented in any way from acting, it matters not that the part impressed, and the nerve communicating with it, be in a condition necessary for the due performance of the function, sensation is not effected. We see this in numerous instances. In pressure on the brain, occasioned by fracture of the skull, or in apoplexy, a disease essentially dependent upon pressure, we find all sensation, all mental manifestation lost; and they are not regained until the compressing cause has been removed. The same thing occurs if the brain be stupefied by opium, or any other narcotic, and, to a less degree, in sleep, or when the brain is engaged in intellectual meditations. Who has not found, that in a state of reverie or brown study he has succeeded in threading his way through a crowded street, carefully avoiding every obstacle, yet so little impressed by the objects around him as not to retain the slightest recollection of them? On the other hand, how vivid are the sensations when the attention is directed to them!

Again, we have numerous cases in which the brain itself engenders the sensation, as in dreams, and in insanity.

In the former we see, hear, speak, make use of every one of our senses apparently, yet there has been no impression from without. Although we may behold in our dreams the figure of a friend long since deceased, there can obviously be no impression made on the retina from without. The whole history of spectral illusions, of morbid hallucinations, and maniacal phantasies, is to be accounted for in this manner. Whether, in such cases, the brain reacts upon the nerves of sense and produces an impression upon them from within, similar to what they experience from without during the production of a sensation, will form the subject of future inquiry.

Pathology also affords several instances where the brain engenders the sensation, most of which are precursory signs of cerebral derangement. The appearance of spots flying before the eyes, of spangles, depravations of vision, of hearing, &c. and a sense of numbness in the extremities, are referable to this cause, as well as the singular fact well known to the operative surgeon, that a pain is often felt in a particular part of a limb, for years after the limb has been removed from the body.

These facts prove, that every sensation, although referred to some organ, must be perfected in the brain. The impression is made upon the nerve of the part, but the appreciation takes place in the common sensorium.

There are but few organs of the body, which could be regarded as insensible, provided we were aware of the precise circumstances under which their sensibility is elicited. The old doctrine,—as old indeed as Hippocrates,—was, that the tendons and other membranous parts are among the most sensible organs of the body. This opinion was implicitly credited by Boerhaave, and his follower Van Swieten, and in many cases had a decided influence,—on surgical practice especially. As the bladder consists principally of membrane, it was agreed for ages by all lithotomists, that it would be improper to cut or divide any part of it; and therefore, in order to extract the stone, dilating instruments were used, which caused the most painful lacerations of the parts implicated in the operation.

Haller considered the tendons, ligaments, periosteum, bones, meninges of the brain, different serous membranes, arteries, and veins, entirely insensible; yet we know, that these parts are exquisitely sensible when attacked with inflammation. One of the most painful affections to which man is liable is the variety of whitlow that implicates the periosteum; and in all affections of the bone, which inflame or press forcibly upon that membrane, we have excessive sensibility exhibited.

Many parts, too, are affected by special irritants; and, after they have appeared insensible to a multitude of agents, will show great sensibility when a particular irritant is applied. Bichat, for example, endeavoured to elicit the sensibility of ligaments in a thousand ways, and without success; but when he subjected them to distention or twisting, they immediately gave evidence of it. It is obvious, then, that before we determine that a part is insensible, we must have submitted it to every kind of irritation. Adelon affirms, that there is no part but what may become painful by disease. From this assertion the cuticle might safely be excepted. It is, so far as we know, totally devoid of blood-vessels and nerves,—the elements of sensibility,—and appears to be extra-organic. If we are right, indeed, in our view of its origin and uses, as described hereafter, sensibility would be of no advantage to it, but the contrary. In the present state, then, of our knowledge, we are justified in asserting, that bones, cartilages, and membranes are not sensible to ordinary external irritation, when in a state of health, or in other words, that we are not aware of the irritants, which are adapted to exhibit their sensibility.

That sensibility is due to the nerves distributed to a part is so generally admitted as not to require comment. It is true, however, that such sensibility is by no means in proportion to the number of nerves it may receive. Nay, some parts are acutely sensible in disease into which nerves cannot be traced. To explain these cases, Reil supposed, that each nerve is surrounded at its termination by a nervous atmosphere, by which its action is extended beyond the part in which it is seated. This opinion is a mere creation of the imagination. We have no evidence of any such atmosphere, and it is more philosophical in us to presume, that the reason we do not discover nerves in these parts may be owing to the imperfection of our vision.

We may conclude, then, that the action of impression occurs in the nerves of the part to which the sensation is referred.

The facts, already mentioned, show, that the action of perception takes place in the brain, and that the nerve is merely the conductor of the impression between the part impressed and that organ. If a ligature be put around a nerve, sensation is lost below the ligature, but it is uninjured above it. If two ligatures be placed, sensibility is lost in the portion included between the ligatures, but is restored if the upper ligature be removed. The spinal marrow is sensible along the whole of its posterior column, but it also acts only as a conductor of the impression. Flourens destroyed the spinal cord from below, by slicing it away, and he found that sensibility was gradually extinguished in the parts corresponding to the destroyed medulla, but that the parts situated above evidently continued to feel. Perception therefore occurs in the encephalon; and not in the whole but in some of its parts. Many physiologists, amongst whom may be mentioned Haller, Lorry, Rolando, and Flourens, have sliced away the brain, and found that the sensations continued until the knife reached the level of the corpora quadrigemina; and again it has been found, that if the spinal cord be sliced away from below upwards, the sensations persist until we reach the medulla oblongata. It is, then, in the medulla oblongata that we must place the cerebral organs of the senses, and it is with this part of the cephalo-spinal axis, that the nerves of the senses communicate.

If we divide the posterior roots of the spinal nerves and the fifth pair, all *general* sensibility is lost; but if we divide the nerves of the senses, we destroy only their functions. We can thus understand, why, after decapitation, sensibility may still remain for a time in the head. It is instantly destroyed in the trunk, owing to the removal of all communication with the encephalon, but the fifth pair remains entire in the head, as well as the nerves of the organs of the senses. Death must of course follow almost instantaneously from loss of blood, but there *may* be an appreciable space, during which the head may continue to feel, or in other words, during which the external senses may act. M. Julia Fontanelle has indeed concluded, from a review of all the observations made on this matter, that, contrary to the common opinion, death by the guillotine is one of the most painful, that could be invented: that the pains of decollation are horrible, and endure even until there is an entire extinction of animal heat!

It has been remarked, that the cerebral hemispheres may be sliced away without abolishing the senses. The experiments of Rolando and Flourens, which have been repeated by Magendie, show, however, that the sight is an exception;—that it is lost by the removal of the hemispheres. If the right hemisphere be sliced away, the sight of the left eye is lost, and *conversely*—one of the facts proving the decussation of the optic nerves. The experiments of these gentlemen show, that vision, more than the other senses, requires a connexion with the organ of the intellectual faculties—the cerebral hemispheres; and this, as Magendie has judiciously remarked, because vision rarely consists in a simple impression made by the light, but is connected with an intellectual process, by which we judge of the distance, size, shape, &c. of bodies.

Having arrived at a knowledge of the part of the encephalon in which perception occurs, our acquaintance with this mysterious process is suddenly arrested. We know not, and we probably never shall know, the action of the brain in accomplishing it. This is certainly not allied to any physical phenomenon, and if ever we are justified in referring a function to the class of the *organic* and *vital*, it would be those, that belong to the elevated phenomena, which we have to consider under the head of the animal functions. We know them but by their results. We are but little better acquainted, however, with many topics of physical inquiry;—with the phenomena of the electrical or magnetic fluid, for example.

The organs, then, that form the media of communication between the parts impressed and the brain, are the nerves and spinal marrow. Broussais, indeed, affirms, that every stimulation, capable of causing perception in the brain, runs through the whole of the nervous system of relation; that it is repeated in the *mucous membranes*, whence it is again returned to the centre of perception, "which judges of it according to the view of the viscus to which the mucous membrane belongs, and adapts its action according as it perceives pleasure or pain."

As we are totally unacquainted with the *material* character of the fluid, which passes with the rapidity of lightning along these cords, it is as impossible for us to describe its mode of transmission, as it is to depict that of the electric fluid along a conducting wire. As in this last case, we are aware of such transmission only by the result. Still, hypotheses, as in every obscure matter of inquiry, have not been wanting. Of these, three are chiefly deserving of notice. The *first*, of greatest antiquity, is, that the brain secretes a subtile fluid, which circulates through the nerves, called *animal spirits*, and which is the medium of communication between the different parts of the nervous system; the *second* regards the nerves as cords, and the transmission as effected by means of the vibrations or oscillations of these cords; whilst the *third* ascribes it to the operation of electricity.

The hypothesis of the *animal spirits* has prevailed most extensively. It was the doctrine of Hippocrates, of Galen, of the Arabians, and of most of the physicians of the last centuries. Descartes adopted it energetically, and was the cause of its more extensive diffusion. The great grounds, assigned for the belief, were, *first*, that as the brain receives so much more blood than is necessary for its own nutrition, it must be an organ of secretion;

secondly, that the nerves seem to be a continuation of the medullary matter of the brain; and it has already been remarked, that Malpighi considered the cortical part of the brain to be follicular, and the medullary to be secretory tubes. It was not unnatural, therefore, to regard the nerves as vessels for the transmission of these spirits. As, however, the animal spirits had never been met with in a tangible shape, ingenuity was largely invoked in surmises regarding their nature; and, generally, opinions settled down into the belief, that the fluid was of an ethereal character. For the various opinions, that have been held upon the subject, the reader is referred to the *Elementa Physiologiæ* of Haller, who was himself an ardent believer in the existence of the animal spirits, and has wasted much time and space in an unprofitable inquiry into their nature.

The truth is, that we have not sufficient evidence, direct or indirect, of the existence of any nervous fluid of the kind described. Notwithstanding the recent observations of Ehrenberg, the nerves do not seem to consist of tubes. Raspail has properly concluded, that the opinion of Bogros and others, that they are hollow, and contain a fluid, is unsupported by facts, for although he admits, that Bogros succeeded in injecting the nerves with mercury, he thinks, that the passage of the metal along the nerves was owing to its having forced its way by gravity. Raspail found the nerve, under the microscope, presenting a homogeneous structure, without the slightest trace of solution of continuity. Nor have we any reason for considering the brain the organ of any ponderable secretion. Yet the term animal spirits, although their existence is not now believed in, adheres to us in popular language. We speak of a man who has a great flow of animal spirits, but without regarding the hypothesis whence the expression originated.

The expression *nervous fluid* is still constantly used by physiologists. By this, however, they simply mean the medium of communication or of conveyance, by which the nervous influence is carried, with the rapidity of lightning, from one part of the system to another, but without committing themselves as to its character; so that, after all, the idea is in part retained, although the term, as applied to the nervous fluid, is exploded.

Good directly admits them under the more modern title; Earle firmly believes in the existence of a circulation in the nervous system,—a view, which was for a long time adopted,—and it is not easy to conceive, that the brain does not possess the function of elaborating some fluid,—galvanoid or other,—which is the great agent in the nervous function.

The hypothesis of vibrations is ancient, but has been by no means as generally admitted as the last. Among the moderns it has received the support of Condillac, Hartley, Blumenbach, and others; some supposing, that the nervous matter itself is thrown into vibrations; others, that an invisible and subtile ether is diffused through it, which acts the sole or chief part. As the latter is conceived, by many to be the mode in which electricity is transmitted along conducting wires, it is not liable to the same objections as the former. Simple inspection, however, of a nerve at once exhibits that it is incapable of being thrown into vibrations. It is soft, never tense, always pressed upon in its course; and, as it consists of filaments destined for very different functions,—sensation, volition, respiratory motion, &c.—we cannot conceive how one of these filaments can be thrown into vibration without the effect being extended to others, and great confusion being thus induced.

The last hypothesis is of later date, subsequent to the discoveries made in animal electricity. The rapidity, with which sensation and volition are communicated along the nerves, could not fail to suggest a resemblance to the mode in which the electric and galvanic fluids fly along conducting wires. Yet the great support of the opinion was in the experiments instituted by Dr. Wilson Philip and others, from which it appeared, that if the nerve proceeding to a part be destroyed, and the secretion, which ordinarily takes place in the part, be thus arrested, the secretion may be restored by causing the galvanic fluid to pass from one divided extremity of the nerve to the other.

The experiments, connected with secretion, will be noticed more at length hereafter. It will likewise be shown, that in the effect of galvanism upon the muscles, there is the same analogy; that the muscle may be made to contract for a length of time after the death of the animal, even when a limb has been removed from the body, on the application of the galvanic stimulus; and comparative anatomy exhibits to us great development of nervous structure in those electrical animals, which surprise us by the intensity of the shocks they are capable of communicating.

Physiologists of the present day, generally, we think, accord with the electrical hypothesis. The late Dr. Young, so celebrated for his knowledge in numerous departments of science, adopted it prior to the interesting experiments of Dr. Philip; and Mr. Abernethy, whilst he is strongly opposing the doctrines of materialism, goes so far as to consider some subtile fluid, not merely as the agent of nervous transmission, but as forming the essence of life itself. Dr. Bostock, however, has remarked, that before the electric hypothesis can be considered proved, two points must be demonstrated; first, that *every* function of the nervous system may be performed by the substitution of electricity for the action of the nerves; and secondly, that *all* the nerves admit of this substitution. This is true, as concerns the belief in the *identity* of the nervous and electrical fluids; but we have, even now, evidence sufficient to show their similarity, and that we are justified in considering the nervous fluid as electroid or galvanoid in its nature, emanating from the brain by some action unknown to us, and distributed to the different parts of the system to supply the expenditure, which must be constantly going on.

Reil and Prochaska are of opinion, that the nervous agency is generated through all the nervous system, and that every part derives sensation and motion from its own nerves. Such likewise is the view of Broussais. Gall, too, considers, that every sensation is effected in the organ to which the mind refers it. We have satisfactorily shown, however, that a communication with the brain is absolutely necessary in all cases, and that we can immediately cut off sensation in the portion of a nerve included between two ligatures, and as instantly restore it by removing the upper ligature and renewing the communication with the brain.

EXTERNAL SENSATIONS.

The external sensations are all those perceptions, occasioned by the impressions of bodies external to the part impressed. They are not confined to impressions made by objects external to us. The hand applied to any part of the body, any two of its parts brought into contact, the presence of its own secretions or excretions, may equally excite them. Adelon has divided the external sensations into two orders—*first*, the *senses*, properly so called, by the aid of which the mind acquires its notion of external bodies and of their different qualities; and *secondly*, those sensations, which are still caused by the contact of some body, and yet afford no information to the mind.

It is by the agency of the organs of the external senses, that we become acquainted with the bodies that surround us. They are the instruments by which the brain receives its knowledge of the universe; but they are only instruments, and cannot be considered as the sole regulators of the intellectual sphere of the individual. This we shall see is dependent upon another and still higher nervous organ,—the brain.

The external senses are generally considered to be five in number; for, although others have been proposed, they may perhaps be reduced to some modification of these five,—*tact* or *touch*, *taste*, *smell*, *hearing*, and *vision*. All these have some properties in common. They are all situated at the surface of the body, so as to be capable of acting with due facility on external bodies. They all consist of two parts;—the one, *physical*, which modifies the action of the body, that causes the impression; the other, *nervous* or *vital*, which receives the impression, and conveys it to the brain. In the eye and the ear, we have better exemplifications of this distinction than in the other senses. The physical portion of the eye is a true optical instrument, which modifies the light, before it impinges upon the retina. A similar modification is produced by the physical portion of the ear on the sonorous vibrations, before they reach the auditory nerve; whilst in the other senses, the physical portion forms part of the common integument in which the nervous portion is situated, and cannot therefore be as easily distinguished.

Some of them, again, are symmetrical; that is, composed of two separate and similar halves, united by a median line,—as the skin, tongue, and nose. The others, the eye and the ear, are in pairs; and this, partly perhaps, to enable us to judge of the distances of external objects. We shall find, at least, that there are certain cases, in which both the organs are necessary for accurate appreciation.

Two of the senses,—vision and audition, have, respectively, a nerve of special sensibility; and, until of late years, the smell has been believed to be similarly situated. In the present state of our knowledge, we cannot decide upon the precise nerve of taste, although it will be seen that a plausible opinion may be indulged on the subject. The general sense of touch is seated in the nerves of general sensibility. All, however, seem intimately connected with one of the nerves of general sensibility,—the fifth encephalic pair,—and, in the case of those senses more particularly, which possess nerves of special sensibility, it is found, that they are under the presidency of this nerve of general sensibility; for, if it be cut, the function is abolished, although the nerve of special sensibility may remain entire.

Constituting instruments by which the mind becomes acquainted with external bodies, it is manifestly of importance, that the senses should be influenced by volition. Most of them are so. The touch has the pliable upper extremity, admirably adapted for the purpose. The tongue is movable in almost every direction. The eye can be turned towards objects in almost all positions, by its own immediate muscles. The ear and the nose possess the least individual motion; but the last four, being seated in the head, are capable of being assisted by the muscles adapted for its movement.

All the senses may be exercised *passively* or *actively*. By directing the attention, we can render the impression much more vivid; and hence the difference between simply seeing, or passive vision, and looking attentively; between hearing and listening; smelling and snuffing; touching and attentively feeling. It is to this active exercise of the senses, that we are indebted for many of the pleasures and comforts of social existence. Yet, to preserve the senses in the vigour and delicacy, which they are capable of acquiring by attention, the impressions must not be too constantly or too strongly made. The occasional use of the sense of smell, under the guidance of volition, may be the test on which the chemist, or the perfumer, or the wine-merchant, may rely in the discrimination of the numerous odorous characteristics of bodies; but, if the olfactory nerves be constantly or too frequently stimulated by excitants of this or any other kind, dependence can no longer be placed upon that means of discrimination. The maxim, that "habit blunts feeling," is true only in such cases as the last. Education can indeed render it extremely acute.

Volition, on the other hand, enables us to deaden the force of sensations. By corrugating the eyebrows and approximating the eyelids, we can diminish the quantity of light when too powerful. We can breathe through the mouth, when a disagreeable odour is exhaled around us; or we can completely shut off the passage by the nostrils, with the aid of the upper extremity. Over the hearing we have less command, as regards its individual action: the upper extremity is here always called into service, when we desire to diminish the intensity of any sonorous impression.

Lastly.—It is a common observation, that the loss of one sense occasions greater vividness in the others. This is only true as regards the senses which administer chiefly to the intellect,—those of touch, audition, and vision, for example. Those of smell and taste may be destroyed, and yet the intellectual senses may be uninfluenced in their action.

The cause of the superiority of the remaining intellectual senses, when one or more has been lost, is not owing to any superior organization in these senses, but is another example of the influence of education. The remaining senses are attentively exerted to compensate for the privation, and become surprisingly delicate.

We proceed to the consideration of the separate senses, beginning with that of *tact* or *touch*, because it is the most generally distributed, and may be regarded as that from which all the others are derived. They are all, indeed, modifications of the sense of touch. In the taste, the sapid body; in the smell, the odorous particle; in the hearing, the sonorous vibration; and in the sight, the particle of light, must impinge upon or *touch* the nervous part of the organ, before sensation can, in any of the cases, be effected.

SECT. I.—SENSE OF TACT OR TOUCH.—PALPATION.

The sense of tact or touch is the general feeling or sensibility, possessed by the skin especially, and which instructs us regarding the temperature and the general qualities of bodies. By some, touch is confined to the sense of resistance alone; and hence they have conceived it necessary to raise into a distinct sense one of the attributes of tact or touch. The sense of heat, for example, has been separated from tact, but we think on insufficient grounds. It properly belongs to the sense we are considering, in the acceptation here given to it, and adopted by all the French physiologists. According to them, tact is spread generally in the organs, and especially in the cutaneous and mucous surfaces. It exists in all animals; whilst touch is exercised only by parts evidently destined for that purpose. It does not exist in every animal. It is nothing more than tact, joined to muscular contraction and directed by volition. So that, in the exercise of tact, we may be esteemed *passive;* in that of touch *active.*

The organs, concerned in touch, execute other functions besides;

and in this respect touch differs from the other senses. Its chief organ, however, is the skin; and hence it is necessary to inquire into its structure, so far as is necessary for our purpose.

Anatomy of the Skin, Hair, Nails, &c.

The upper classes of animals agree in possessing an outer envelope or skin, by which the insensible perspiration passes; a slight degree of absorbtion takes place; the parts beneath are protected; and the sense of touch is accomplished.

In man, the skin consists of four parts,—the cuticle, rete mucosum, corpus papillare, and corium.

1. The *epidermis* or cuticle is the outermost layer. It is a dry, membranous structure, devoid of vessels and nerves, and decidedly the most inorganic part of the body. It is, so far as we know, entirely insensible, and takes no part in the functions of the true skin, or in its diseases. It resists putrefaction for a long time, and may be easily obtained, in a separate state from the other layers, by maceration in water. It is the thin pellicle raised by a blister.

The cuticle is probably a secretion from the true skin, which concretes on the surface, becomes dried, and affords an efficient protection to the corpus papillare beneath. It is composed, according to some, of concrete albumen; according to others, of mucus.

The epidermis is said to be pierced by oblique pores for the passage of hairs, and for the orifices of exhalant and absorbent vessels. Humboldt, however, asserts, that he has never seen these pores, even with a microscope which magnified 312,400 times. It is probable, that this inorganic substance is placed at the surface of the body, not simply to protect the corpus papillare, but to prevent the constant imbibition and transudation that might take place did no such envelope exist. The cuticle exfoliates, in the form of scales, from our heads; and, in large pieces, from every part of the body, after certain cutaneous diseases. According to Raspail, the epidermis is formed of a collection of vesicles deprived of their contents, closely applied together, dried, and thrown off in the form of branny scales. He regards it as the outer layer of the corium.

2. The *corpus* or *rete mucosum*, *rete Malpighii* or *mucous web*, is the next layer. It was considered by Malpighi as mucus, secreted by the papillæ, and spread on the surface of the corpus papillare, to preserve it in the state of suppleness necessary for the performance of its functions. In this rete mucosum, the colouring matter of the races seems to exist. It is white in the European, and those of European descent; black in the African, or rather in the Ethiopian; and copper-coloured in the mulatto. Gaultier considers the rete mucosum to be composed of four layers, but this notion is not universally admitted, and scarcely concerns the present inquiry.

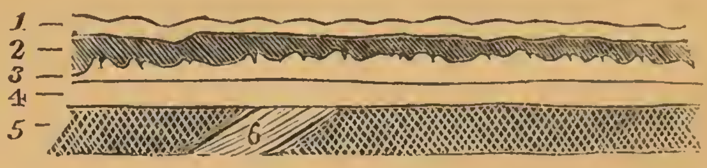
3. The *corpus papillare* is seated next below the rete mucosum. It consists of a collection of small papillæ, formed by the extremities

of nerves and vessels, which, after having passed through the corium beneath, are grouped in small pencils or villi in a spongy, erectile tissue. These pencils are disposed in pairs, and, when not in action, are relaxed, but become erect when employed in the sense of touch. They are very readily seen, when the cutis vera is exposed by the action of a blister, and are always evident at the palmar surface of the hand, and especially at the tips of the fingers, where they have a concentric arrangement. These villi are sometimes called the papillæ of the skin.

4. The *corium, cutis vera, derma*, or *true skin*, is the innermost of the layers of the skin. It consists of a collection of dense fibres, intersecting each other in various directions, and leaving between them holes for the passage of vessels and nerves. It forms a firm stratum, giving the whole skin the necessary solidity for accomplishing its various ends.

The true skin consists chiefly of gelatine. Hence it is used in the manufacture of glue. Gelatine, when united with tannin, forms a substance which is insoluble in water; and it is to this combination, that leather owes the properties it possesses. The hide is first macerated in lime-water to remove the cuticle and hairs, and leave the corium or gelatine. This is then placed in an infusion of oak bark, which contains the tannin. The tannin and the skin unite, and leather is the product.

Fig. 16.



1. Cuticle.
2. Rete mucosum.
3. Corpus papillare.
4. Cutis vera.
5. Cellular membrane.
6. Panniculus carnosus.

These four strata constitute the *skin*, as it is commonly called; yet all are comprised in the thickness of two or three lines. The cutis vera is united to the structures below by *cellular membrane;* and this, with the layers external to it, forms the *common integument.* In certain parts of the body, and in animals more particularly, the cutis vera is adherent to muscular fibres; inserted more or less obliquely, as at 6, Fig. 16. These form the *muscular web* or *panniculus carnosus.* The layer is well seen in the hedgehog and porcupine, in which it rolls up the body, and erects the spines; and in birds, it raises the feathers. In man, it can hardly be said to exist. Some muscles, however, execute a similar function. By the occipito-frontalis, for instance, many persons can move the hairy scalp: by the dartos, the skin of the scrotum can be corrugated. These two parts, therefore, act as *panniculi carnosi.*

In the skin, are situated numerous *sebaceous follicles* or *crypts,* which separate an oily fluid from the blood, and pour it over the surface to lubricate and defend it from the action of moisture. They are most abundant, where there are folds of the skin, or hairs, or where the surface is exposed to friction. We can generally see them on the pavilion of the ear, and their situation is often indicated by small dark spots on the surface, which, when pressed between the fingers, may be forced out along with the sebaceous secretion, in the form of small worms. By the vulgar, indeed, these are considered to be worms. The follicular secretions will engage us hereafter. At present, it is sufficient to remark, that they differ materially according to the part of the body where they exist;—the characters of the fluid, secreted in the axillæ, groins, feet, &c. varying considerably.

The consideration of the hair belongs naturally to that of the skin. The roots of the hair are in the form of bulbs, taking their origin in the cellular membrane. Each bulb consists of two parts,—an outer, which is vascular, and from which the hair obtains its nourishment,—and an inner, which is membranous, and forms a tube or sheath to the hair, during its passage through the layers of the skin. The hair itself consists of a horny, external covering, and a central part, called the *medulla* or *pith*. When we take hold of a hair by the base, with the thumb and fore finger, and draw it through them from the root towards the point, it feels smooth to the touch; but if we draw it through, from the point to the root, we feel the surface rough, and it offers considerable resistance. It is, therefore, concluded, that the hair is bristled, or consists of eminences pointing towards its outer extremity, and it is upon this structure, that the operation of felting is dependent—the hairs being mechanically entangled together, and retained in that state by the inequalities on their surface. Observers have, however, frequently failed in detecting this striated appearance, by the aid of the microscope; and Dr. Bostock affirms, that he had an opportunity of viewing the human hair, and the hair of various kinds of animals, in the excellent microscope of Mr. Bauer, but without being able to detect it. Still, Bichat and, more recently, Dr. Goring, have assigned this as their structure;—the fact having been exhibited by the microscope, and, in their minds, admitting of no doubt.

The colour of the hair is singularly different in different races and individuals. By some, this is considered to depend upon the fluids contained in the pith. Vauquelin analyzed the hair most attentively, and found that it consists chiefly of an animal matter, united to a portion of oil, which appears to contribute to its flexibility and cohesion. Besides this, there is another substance, of an oily nature, from which he considers the colour of the hair to be derived. The animal matter, according to that chemist, is a species of mucus, but other chemists believe it to be chiefly albumen. Vauquelin found that the colouring matter of the hair is destroyed by acids; and he suggests, that when it has suddenly changed colour and become gray, in consequence of any great mental agitation, this may be owing to the production of an acid in the system, which acts upon the colouring matter. The explanation is purely hypothetical, and is considered, and characterized as such by Dr. Bostock; but the same objection must be admitted to apply to the view he has substituted. He conceives it "more probable, that the effect depends upon the sudden stagnation of the vessels, which secrete the colouring matter, while the absorbents continue to act and remove that which already exists." There is no more real evidence of "stagnation of vessels" than there is of the formation of an acid. Our knowledge is limited to the fact, that there is a sudden and decided change in the whole pileous system after great or prolonged mental agitation. But a similar, though more gradual change, is produced by age. We find persons entirely gray at a very early period of life; and, in old age, the change happens universally. It is not then difficult to suppose, that some alteration in the nutrition of the hair may be induced, resembling that which occurs under these circumstances. Dr. Bostock doubts the fact of such sudden conversions; but the instances are too numerous for us to consider them entirely fabulous. Besides, as we have seen, the cases are not so preternatural as they might at first sight appear. The change induced is identical with that which occurs naturally to every individual, sooner or later. Lepelletier ascribes the change of colour to two very different causes.—*First*, owing to defective secretion of the colouring fluid, without any privation of nutrition. In this case, the hairs may live and retain their hold, as we observe in young individuals:—and *secondly*, the canals, which convey the fluid into the hair may be obliterated, as in old age. The same cause, acting on the nutritious vessels of the bulb, produces, successively, privation of colour, death and loss of these epidermoid productions. According to other physiologists, the seat of colour is in the horny covering of the hair; and, in the largest hairs or spines of the porcupine, this seems to be the case, the pith being manifestly white, and the horny covering coloured.

The exact relations between the cuticle, the rete mucosum and the hair are not known. It is not determined, whether the layers are simply perforated by the hair in its passage outwards, or whether they furnish it coats as it proceeds along. There is often, however, an intimate relationship observed between the colour of the hair and that of the rete mucosum. The fair complexion is accompanied with light hair;—the swarthy with dark;—and we see the connexion still more signally displayed in those animals, that are spotted—the colour of the hair being variegated like that of the skin.

Hairs differ very materially, according to the part of the body on which they appear. In some parts they are short, as in the armpits, whilst on the head it is not easy to say what would be the precise limit to the growth, were they left entirely to nature. In the Malays, it is by no means uncommon to see them touch the ground.

The hair has various names assigned to it, according to the part on which it appears,—as *beard*, *whiskers*, *mustachios*, *eyebrows*, *eye-*

lashes, &c. In many animals it is long and straight; in others crisped, when it is called *wool.* If stiff, it is termed a *bristle;* if inflexible, a *spine.*

The hairs are entirely insensible, and, excepting in their bulbous portion, are not liable to disease. Dr. Bostock affirms, that under certain circumstances they are subject to a species of inflammation, when vessels may be detected, at least in some of them, and they become acutely sensitive. The sensibility of the hair, under any known circumstance, may, however, be doubted. It appears to be almost inorganic, except at its root; and, like the cuticle, resists putrefaction for a great length of time. Bichat and Gaultier were of the opinion of Dr. Bostock;—misled, apparently, by erroneous reports concerning the plica polonica; but Baron Larrey has satisfactorily shown, that the affection is confined to the bulbs, and that the hairs themselves continue totally devoid of sensibility.

It is difficult to assign a plausible use for the hair. That of the head has already engaged our attention; but the hair, which appears on certain parts at the age of puberty and not till then, and that on the chin and upper lip of the male sex only, set our ingenuity at defiance. In this respect, however, the hair is not unique. Who can venture to suggest a probable use for the nipple on the male breast? Many physiologists regard certain parts, which exist in one animal, apparently without function, but which answer useful purposes in another,—as *vestiges* to indicate the harmony, which reigns through nature's works. The useless nipple on the breast of one sex might be regarded in this light; but the tufts of hair on various parts cannot, in any way, be assimilated to the hairy coating, that envelopes the bodies of animals, and is, in them, manifestly intended as a protection against cold.

There is another class of bodies, connected with the skin, and analogous in nature to the last described,—the *nails.* These serve a useful purpose in touch, and consequently require notice here.

In the system of M. De Blainville, they constitute a subdivision of the hairs, which he distinguishes into *simple* and *compound*—*simple*, when each bulb is separated, and has a distinct hair—*compound*, when several pileous bulbs are agglomerated, so that the different hairs, as they are secreted, are cemented together to form one solid body of greater or less size,—a *nail*, *scale*, *horn*, &c.

In man, the nail alone exists, the chief and obvious use of which is to support the pulp of the finger, whilst it is exercising touch.

Animals are provided with horns, beaks, hoofs, nails, spurs, scales, &c. All these, like the hair, grow from roots, and are considered to be analogous in their physical and vital properties. Meckel, and De Blainville are, indeed, of opinion, that the teeth are of the same class, and that they belong, originally, to the skin of the mouth. The latter zoologist, who has been distinguished for his labours in natural science, considers the hair to be the rudiment of every constituent of the skin, and even of every organ of sense; the eye and the ear being, in his view, bulbs analogous to those of the hair, but considerably modified, so as to adapt them to the extremely delicate functions they have to execute!

For physiological purposes the above description is enough, and more than enough. A few words will be necessary regarding the *mucous membranes*, which resemble the skin so much in their properties, as to be, with propriety, termed *dermoid*. If we trace the skin into the various outlets, we find, that a continuous, soft, velvety membrane exists through their whole extent; and, if the channel have two outlets, as in the case of the alimentary canal, this membrane, at each outlet, commingles with the skin, and appears to differ but slightly from it. So much, indeed, do they seem to form part of the same organ, that physiologists have described the absorption, which takes place from the intestinal mucous membrane, as *external*. They cannot, however, in the higher order of animals, be considered completely identical; nor is the same membrane alike in its whole extent. They have all been referred to two great surfaces—the *gastro-pulmonary*—comprising the membranes of the outer surface of the eye, of the ductus ad nasum, of the nose, of the mouth, and of the respiratory and digestive passages; and the *genito-urinary*—which line the whole of the genital and urinary apparatuses. In addition to these, a membrane of similar character lines the meatus auditorius externus, and the excretory ducts of the mammæ.

In the mucous membranes—especially at their extremities, which appear to be alone concerned in the sense of touch, the same superposition of strata exists as in the skin—viz. epidermis, rete mucosum, corpus papillare, and cutis vera. They have likewise similar follicles, called *mucous*, but nothing analogous to the hairs, unless we regard the teeth to be so, in correspondence with the phantasies of Meckel, and De Blainville.

The analogy between the skin and mucous membranes is farther shown, by the fact, that if we invert the polypus, the mucous membrane gradually assumes the characters of the skin, and the same circumstance is observed in habitual descents of the rectum and uterus.

Physiology of Tact and Touch.

In describing the physiology of the sense of touch it will be convenient to revert to the distinction, already made, between the sense when passively and when actively exerted, or between *tact*, and *touch*. The mode, however, in which the impression is made on each is alike, and equally simple. It is merely necessary, that the substance, which has to cause it, should be brought in contact with the physical part of the organ—the cuticle; the nervous part is seated in the corpus papillare, for if the nerves proceeding to this layer of the skin be cut, the sense becomes destroyed. In the exercise of touch, each of the layers seems to have its appropriate office: the corium, which forms the innermost layer—the base on which the others rest—offers the necessary resistance, when bodies are applied to the surface; the rete mucosum is either unconcerned in the function, or keeps the corpus papillare in the necessary state of suppleness: the erectile tissue, on which the papillæ are grouped, probably aids them in their appreciation of bodies; and the epidermis modifies the tactile impression, which might become too intense, or be painful, did this envelope not exist. The degree of perfection of the sense is, indeed, greatly influenced by the state of the cuticle. Where it is thin,—as upon the lips, glans penis, clitoris, &c.—the sense is very acute; but, where thick and hard, it is very obtuse; and, where removed,—as by blistering,—the contact of bodies gives pain, but does not occasion the appropriate impressions of touch.

It has been supposed, that some of the recorded instances of great resistance to heat have been caused by unusual thickness, and compactness of cuticle, together with a certain degree of insensibility of the skin. The latter may be an important element in the explanation, but some of the feats, executed by persons of the character alluded to, could hardly have been influenced by the former, as the resistance seemed almost equally great in the delicately organized mucous membranes. A Madame Girandelli,—who exhibited in Great Britain, many years ago,—was not only in the habit of drawing a box with a dozen lighted candles along her arm, and of putting her naked foot upon melted lead, but of dropping melted sealing-wax upon her tongue, and impressing it with a seal, without appearing to experience the slightest uneasiness; and, some years ago, (1832,) a man of the name of Chabert excited in this country, the surprise, which followed his exhibitions in London a year or two previously, and which gained him the appellation of the "Fire King." In addition to the experiments performed by Madame Girandelli, Chabert swallowed forty grains of phosphorus, washed his fingers in melted lead, and drank boiling Florence oil with perfect impunity. In the case of the phosphorus he professed to take an antidote, and doubtless did so. It is probable, also, that agents were used by him to deaden the painful impressions ordinarily produced by hot bodies, when applied to the surface. A solution of borax or alum, spread upon the skin is said to exert a powerful effect of this kind; but, in addition to the use of such agents, there must be a degree of insensibility about the corpus papillare, otherwise it is difficult to understand why these hot substances did not injure the coats of the stomach. We see, daily, striking differences in the sensibility of the mucous membrane of the mouth and gullet, and are frequently surprised at the facility with which certain persons swallow fluids, at a temperature, which would excite the most uneasy sensations in others. In this, habit has unquestionably much to do.

In the mucous membranes, tact is effected precisely in the same way as in the skin. The layers, of which it is constituted, participate in like manner; but the sense is more exercised at the extremities of the membrane than internally. The food, received into the mouth, is felt there, but after it has passed into the gullet it excites hardly any tactile impression, and it is not until it reaches the lower part of the membrane, in the shape of excrement, that its presence is again indicated by the sense of tact.

Pathologically, we have some striking instances of this difference in the different parts of a mucous membrane. If an irritation exists within the intestinal canal, the only notice we may have of it is by itching of the nose,—in other words, at one of the extremities of the membrane. In like manner, a calculus in the bladder is indicated by itching of the glans penis. A similar exemplification is offered during the passage of a gall-stone through the ductus communis choledochus;—the duct formed by the union of a canal proceeding from the liver with another from the gall-bladder, and which opens into the small intestine. Calculi occasionally form in the biliary passages, and, after a time, enter the common duct in their way to the intestine. On their first entrance, the pain experienced is of the most violent character; but this, after a time, subsides, as soon, indeed, as the calculus has got fairly into the canal; but violent irritation is again experienced, when it is about to clear the duct, and enter the intestine.

One of the great purposes of the sense of tact is to enable us to judge of the temperature of bodies. This office it executes alone. No other sense participates in it. It requires no previous exercise; it is felt equally by the infant and the adult, and requires only the proper development of its organs.

The relative temperature of bodies is accurately designated by the instrument called the *thermometer;* very inaccurately by our own sensations, and the reason of this inaccuracy is sufficiently intelligible. In both cases, the effect is produced by the disengagement of a subtile fluid, called *caloric* or the matter of heat, which pervades all bodies, and is contained in them to a greater or less extent. This caloric is constantly passing, and repassing, between bodies, either by radiation or by positive contact, until they attain the like temperature, or until there is an equilibrium of caloric, and all have the same temperature as indicated by the thermometer. Hence, objects in the same apartment will exhibit, *cæteris paribus*, the same temperature by this test. From this law, however, the animal body must be excepted. The power, which it possesses of generating its own heat, and of counteracting the external influences of temperature, preserves it constantly at the same point. This will fall under consideration in another place.

Although, however, all objects may exhibit the same temperature, in the same apartment, when the thermometer is applied to them, the sensations experienced may be very different. Hence the difficulty, which the uninstructed have in believing that they are actually of identical temperature;—that a hearth-stone, for instance, is of the same degree of heat as the carpet in a chamber. The cause of the different sensations, experienced in the two cases, is, that the hearth-stone is a much better *conductor* of the matter of heat than the carpet. The consequence is, that caloric is more rapidly abstracted by it from the part of the body, which comes in contact with it, than it is by the carpet; and the stone appears to be the colder of the two. For the same reason, when these two substances are raised in temperature above that of the human body, the hearth-stone will appear the hotter of the two; because, it conducts caloric and communicates it more rapidly to the body than the carpet.

When the temperature of the surrounding air is higher than 98°, we receive caloric from the atmosphere, and experience the sensation of heat. The human body is capable of being penetrated by the caloric of substances exterior to it, precisely like those substances themselves; but, within certain limits, it possesses the faculty of consuming the heat and retaining the same temperature.

When the temperature of the atmosphere is only as high as our own—an elevation which it not unfrequently attains in many parts of the United States—we still experience the sensation of unusual warmth: yet no caloric is communicated to us. The cause of this feeling is, that we are accustomed to live in a medium of a less elevated temperature, and consequently to give off caloric habitually to the atmosphere.

Lastly, in an atmosphere of a temperature much lower than that of the body, heat is incessantly abstracted from us; and, if rapidly abstracted, we have the sensation of great cold.

From registers, kept by the illustrious founder of the University of Virginia, Mr. Jefferson, at his residence at Monticello, lat. 37°, 58′, long. 78°, 40′, it appears, that the mean temperature of this part of Virginia is about 55½ or 56°; that the thermometer varies from 5½° in the coldest month, to 94° in the warmest. Now, the temperature of the human body being 98°, it follows, that heat must be incessantly abstracted from us, and that we ought there to experience constantly the sensation of cold. This we should unquestionably do, were we not protected by clothing, and aided by the artificial temperature of our fires during the colder seasons. The influence of our own bodily powers and secretions in the generation of heat is interesting and important, but it does not materially concern us here.

Yet, accustomed as the body is to give off caloric, there is a temperature, which, clothed as we are, does not communicate to us the sensation of cold, although we may still be disengaging heat to some extent. This temperature may perhaps be fixed somewhere between 70° and 80°, in the climate of the middle portions of the

United States. So much, however, are our sensations in this respect dependent upon the temperature, which has previously existed, that the *comfortable point* will be found to vary at different seasons. If the thermometer, for instance, has ranged as high as 98°, and if, for a few days, it has maintained this elevation, a depression of 15° or 20° will be accompanied by feelings of discomfort; whilst a sudden elevation from 30° to 75° may occasion an oppressive feeling of heat. During the voyages, made by Captain Parry and others, to discover a north-west passage, it was found, that after having lived for some days in a temperature of 15° or 20° below 0, it felt quite mild and confortable when the thermometer rose to zero, and conversely.

This is the great source of the deceptive nature of our sensations of warmth or cold. They enable us merely to judge of the comparative conditions of the present and the past; hence it is, that a deep cellar appears warm to us in winter and cool in summer. At a certain distance below the surface, the temperature of the earth indicates the medium heat of the climate; yet, although this may be stationary, our sensations on descending to it in winter and in summer would be by no means the same. If two men were to meet each other on the middle of the South American Andes,—the one having descended, and the other ascended,—their sensations would be very different. The one, who had descended, coming from a colder to a warmer atmosphere, would feel warm; whilst the traveller, who had ascended, would feel correspondently cool. An experiment, often performed in the chemical lecture-room, although strictly physiological, exhibits the same fact. If, after having held one hand in iced water, and the other in warm, we plunge both into water of a medium heat, it will seem warm to the first hand and cold to the other.

But our sensations are not guided solely by bodies surrounding us. They are often greatly dependant, especially in disease, on the state of the animal economy itself. If the power, which the system possesses of forming heat, be morbidly depressed—or if, in consequence of old age, or of previous sickness, calorification does not go on regularly and energetically, a temperature of the air, which to the vigorous is agreeable, may produce an unpleasant impression of cold. Under opposite circumstances, a feeling of heat will exist.

By tact we are likewise capable of forming a judgment regarding many of the qualities of bodies,—such as their size, consistence, weight, distance, and motion. This faculty, however, is not possessed exclusively by the sense in question. We can judge, for example, of the size of bodies by the sight; of distances, to a certain extent, by the ear, &c. To appreciate these characteristics, it is necessary, that the sense should be used actively, and that we should call into exercise the admirable instrument with which we are provided for that purpose.

In treating of the external senses generally, it was remarked, that we are capable of judging, by their aid, of impressions made on us by portions of our own body. By the sense of touch we can derive information regarding its temperature, shape, consistence, &c. An opinion has, indeed, been advanced, that this sense is best adapted for proving our own existence, as every time that two portions of the body come into contact, two impressions are conveyed to the brain, whilst if we touch an extraneous body we have but one.

The tact of the mucous membranes is extremely delicate. The great sensibility of the lips, tongue, conjunctiva, Schneiderian membrane, lining membrane of the trachea and urethra is familiar to all. Excessive pain is produced in them by the contact of extraneous bodies; yet, in many cases, we have the effect of habit in blunting sensation singularly exemplified. The first introduction of a bougie into the urethra will produce intense irritation; but after a few repetitions the sensation will become scarcely disagreeable.

To appreciate accurately the shape and size of objects, it is necessary, that they should be embraced by a part of the body, which can examine their various surfaces and be applied to them in every direction. In man, the organ well fitted for this purpose, is the hand.

This is situated at the free extremity of a long and flexible member, which admits of its being moved in every direction, and renders it not only well adapted for the organ of touch but for that of prehension, as will be seen in another place. Man alone possesses a true hand; for although other animals have organs of prehension very similar to his, they are much less complete. Aristotle, indeed, and Galen term it the *instrument of instruments*. The chief superiority of the hand consists in the size and strength of the thumb, which stands out from the fingers and can be brought in opposition to them, so as to enable us to grasp bodies, and to execute various mechanical processes under the guidance of the intellect. So important an organ was the thumb esteemed by Albinus, that he called it a lesser hand assisting the larger—"*manus parva majori adjutrix*," and its construction has been considered worthy of forming the subject of one of the 'Bridgewater Treatises'—'on the power, wisdom, and goodness of God, as manifested in the creation,'—a task assigned to Sir Charles Bell.

In addition to the advantages referred to, the hand is furnished with a highly sensible integument. The papillæ are largely developed, especially at the extremities of the fingers, where they are ranged in concentric circles, and rest upon a spongy tissue, by many physiologists considered to be erectile, and, if not, serving as a cushion. At the posterior extremity of the fingers, the nails are situated, which support the pulps of the fingers behind, and render the contact with bodies more immediate. This happy organization of the soft parts of the hand alone concerns the sense of touch directly. The other advantages, which it possesses, relate to the power of applying it under the guidance of volition.

Of the mode in which touch is effected it is not necessary to treat. Being nothing more than tact, exerted by an appropriate instrument, the physiology of the two must be identical.

Metaphysicians have differed widely regarding the services that ought to be attributed to the touch. Some have greatly exaggerated them, considering it the *sense par excellence*, or the *first of the senses*. It is an ancient notion to ascribe the superiority of man over animals and his pre-eminence in the universe—his intelligence, in short—to the hand. Anaxagoras asserted, and Helvetius revived the idea, "that man is the wisest of animals because he possesses hands." The notion has been embraced, and expanded by Condillac, Buffon, and many modern physiologists and metaphysicians. Buffon, in particular, assigned so much importance to the touch, that he believed the cause, why one person has more intellect than another, is, his having made a more prompt and repeated use of his hands from early infancy. Hence he recommended, that infants should be allowed to use them freely from the moment of birth. Other metaphysicians have considered the hand the source of our mechanical capabilities.

The same answer applies to all these views. The hand can only be regarded as an instrument by which information of particular kinds is conveyed to the brain, and by which other functions are executed, under the direction of the will. The idiot has the sense frequently more delicate than the man of genius or than the best mechanician, whilst the most ingenious artists have by no means the most delicate touch. But we have some striking cases to show, that the hand is not entitled to this extravagant commendation. Not many years ago, a Miss Biffin was exhibited in London, who was totally devoid of both upper and lower extremities. Yet she was unusually intelligent and ingenious. It was surprising to observe the facility with which she hem-stitched, turning the needle with the greatest rapidity in her mouth, and inserting it by means of the teeth. She also painted miniatures faithfully, and beautifully;—holding the pencil between her head and neck. All her motions were, in fact, confined to the tongue and lips, and to the muscles of the neck.

Magendie, in the second edition of his physiology, alludes to a similar case. He says, that there was, at that time, (1825,) in Paris, a young artist, who had no signs of arm, forearm, or hand, and whose feet had one toe less than usual—the second; yet his intelligence was, in no respect, inferior to that of boys of his own age; and he even gave indications of distinguished ability. He sketched and painted with his feet. Within the last few years, a Miss Honeywell, born without arms, has travelled about this country. She acquired so much dexterity in the use of the scissors, as to be able, by holding them in her mouth, to cut likenesses, watch papers, flowers, &c. She also writes, draws, and executes all kinds of needle-work with the utmost ease and despatch.

How fatal are these authentic examples to the views of Helvetius, and others!

But, it has been said, the touch is the least subject to error of all the senses, and that it is the *regulating*—the *geometrical* sense. In part only is this accurate. It certainly possesses an advantage in having the organ brought into contact with the body that excites the impression, whilst, in the cases of vision and olfaction, the organ receives only the impression of an emanation from the body; and, in that of audition, a vibration only of an intervening medium.

Yet some of the errors into which it falls are as grievous as those that happen to the other senses. How inaccurate is its appreciation of the temperature of bodies! We have attempted to show, that it affords merely relative knowledge,—the same substance appearing hot or cold to us, according to the temperature of the substance previously touched. Nay, this infallibility so little exists, that we have the same sensation communicated to us by a body, that rapidly abstracts caloric from us, as by one that supplies it rapidly. By touching frozen mercury, which requires a temperature of —40° of Fahrenheit to congeal, we experience the sensation of a burn!

Again, if we cross the fingers and touch a rounded body—a marble, for instance—with two of the pulps at the same time; instead of experiencing the sensation of one body, we feel as if there were two,—an illusion produced by the lateral portions of fingers being brought in opposition, which are naturally in a different situation, and at a distance from each other; and, as these two parts habitually receive distinct impressions when apart, they continue to do so when applied to opposite sides of the rounded body.

It has been asserted, again, that the touch is the great corrector of the errors into which the other senses fall. But let us inquire, whether, in this respect, it possesses any decided superiority over the other senses. For this purpose, it is well to adopt the distinction, made by Spurzheim and others, of the functions of the senses into *immediate* and *mediate*. Each sense has its immediate function, which it possesses exclusively; for which, in other words, no other can be substituted. The touch instructs us regarding temperature; the taste appreciates savours; the smell, odours; audition, sound; and vision, colours. These are the *immediate* functions of the senses, each of which can be accomplished by its own organs, but by no other. As concerns the immediate functions of the senses, therefore, the touch can afford no correction. Its predominance, as regards the *mediate* functions of the senses, is likewise exaggerated. The *mediate* functions are those that are auxiliary to the senses, consisting in the impressions they furnish to the mind, and by aid of which it acquires its notions of bodies. The essential difference between these two sets of functions is,—that the mediate can be effected by several senses at once. Vision, olfaction, and audition, participate in judging of distances, as well as touch; the sight instructs us regarding shape, &c. It has, indeed, been affirmed by metaphysicians, that the touch is necessary to several of the senses to give them their full power; that we could form no notion of the size, shape, and distance of bodies, unless instructed by this sense. The remarks, already made, have proved the inaccuracy of this opinion. The farther examination of it will be resumed under the subject of vision. The senses are, in truth, of mutual assistance. If the touch falls into error, as in the case of inaccurate appreciation of temperature, the sight, aided by appropriate instruments, dispels it. If the crossed fingers convey to the brain the sensation of two rounded bodies, when one only exists, the sight apprizes us of the error; and if the sight and touch united impress us with a belief in the identity of two liquids, the smell or the taste will often detect the erroneous inference.

But, it has been said by some, touch is the only sense that gives us any notion of the existence of bodies. Destutt-Tracy has satisfactorily opposed this, by showing, that our notion of the existence of bodies is a work of the mind, in the acquiring of which the touch does not assist more immediately than any other sense. "The tactile sensations," he observes, "have not of themselves any prerogative essential to their nature, which distinguishes them from every other. If a body affect the nerves beneath the skin of my hand, or if it produce certain vibrations in those distributed on the membranes of my palate, nose, eye, or ear, it is a pure impression, which I receive; a simple affection, which I experience; and there seems to be no reason for believing, that one is more instinctive than another; that one is more adapted than another for enabling me to judge that it proceeds from a body exterior to me. Why should the simple sensation of a puncture, burn, titillation, or pressure, give me more knowledge of the cause, than that of a colour, sound, or internal pain? There is no reason for believing it." There are, indeed, numerous classes of bodies, regarding whose existence the touch affords us not the slightest information, but which are detected by the other senses. On the whole, then, we must conclude, that the senses mutually aid each other in the execution of certain of their functions; but that each has its province, which cannot be invaded by any of the others; and that too much preponderance has been ascribed to the touch by metaphysicians and physiologists. Administering, however, so largely to the mind, it has been properly ranked with vision and audition as an intellectual sense.

By education, the sense of touch is capable of acquiring extraordinary acuteness. To this circumstance we must ascribe the surprising facts we occasionally meet with in the blind. Saunderson,—who lost his eyesight in the second year of his life, and was Professor of Mathematics at Cambridge, England,—could discern false from genuine medals, and had a most extensive acquaintance with numismatics. Baczko, referred to by Rudolphi, and who describes his own case, could distinguish between samples of woollen cloth of equal quality but of different colours. The black appeared to him among the roughest and hardest; to this succeeded dark blue and dark brown, which he could not, however, distinguish from each other. The colours of cotton and silk stuff he was unable to discriminate, and he properly enough doubts the case of a Count Lynar, who was blind, and said to be capable of judging of the colour of a horse by the feel. The only means the blind can possess of discriminating colours must be in the inequalities of surface produced by them; and if these were insufficient to enable Baczko to detect the differences between cotton and silk fabrics, it is not probable, that the sleek surface of the horse would admit of such discrimination.

In animals the organ of touch varies. The monkey's resembles that of man. In other quadrupeds it is seated in the lips, snout or proboscis. In molluscous animals the tentacula, and in insects, the antennæ or feelers, are organs of touch, possessing, in some, very great sensibility. Bats appear to have this sensibility to an unusual degree. Spallanzani observed these animals, even after their eyes had been destroyed and ears and nostrils shut up, flying through intricate passages, without striking against the walls, and dexterously avoiding cords and lines placed in their way. The membrane of the wings is, in the opinion of many, the organ that receives the impression produced by a change in the resistance of the air; but some experiments, made by Mr. Broughton, sanction the idea, that it may be dependent upon their whiskers. These whiskers, which are found on the upper lip of feline and other animals, are plentifully supplied with nerves, which seem to proceed from the second branch of the fifth pair, and are lost in the substance of the bristles. In an experiment, which Mr. Broughton made on a kitten, he found that whilst the whiskers were entire, it was capable of threading its way, blindfolded, out of a labyrinth, in which it was designedly placed; but that it was totally unable to do so when the whiskers were cut off.. It struck its head repeatedly against the sides; ran against all the corners; and tumbled over steps placed in its way, instead of avoiding them, as it did prior to the removal of the whiskers.

From facts like these Mr. Broughton drew the conclusion, that certain animals are supplied with whiskers for the purpose of enabling them to steer clear of opposing bodies in the dark.

Sect. II.—SENSE OF TASTE OR GUSTATION.

The sense of taste teaches us the quality of bodies called *sapidity*. It is more nearly allied to touch, in its mechanism, than any other of the senses, as it requires the immediate contact of the body with the organ of taste; and as that organ is, at the same time, capable of receiving tactile impressions, distinct from those of taste. Of this we have a striking example. If we touch various parts of the tongue with the point of a needle, we find two distinct perceptions occasioned. In some parts we experience the sensation of a pointed body without savour; and in others a metallic taste is manifested. Pathological cases, too, exhibit, that the sense of taste may be lost, whilst the general sensibility remains,—and conversely. The organ of gustation is not, therefore, restricted to the production of that sense, but participates in the sense of touch. Yet so distinct are those functions, that the touch can, in no wise, supply the place of its fellow, in detecting the sapidity of bodies. This last is the *immediate* instruction afforded by gustation.

Anatomy of the Organs of Taste.

The chief organ of taste is the tongue, or rather the mucous membrane covering the upper surface, and sides of that organ. The lips, inner surface of the cheeks, the palate, and fauces, participate in the function, especially when particular savours are concerned. Magendie includes the œsophagus and stomach, but we know not on what grounds. His subsequent remarks, indeed, controvert the idea. The lingual branch of the fifth pair is, according to him, incontestably the nerve of taste; and, as this nerve is distributed to the mouth, we can understand, why gustation should be effected there, but not how it can be accomplished in the œsophagus and stomach. The tongue consists, almost entirely, of muscles, which give it great mobility, and enable it to fulfil the various functions assigned to it; for it is not only the organ of taste, but of mastication, deglutition, and articulation. These muscles, being under the influence of volition, enable the sense to be executed passively or actively.

As regards gustation, the mucous membrane is the portion that immediately concerns us. This is formed, like the mucous membranes in general, of the different layers already described. The corpus papillare, however, requires additional notice. If the surface of the tongue be examined, it will be found to consist of myriads of fine papillæ or villi, giving the organ a velvety appearance. These papillæ are, doubtless, formed like those of the skin, of the final ramifications of nerves, and of the radicles of exhalant and absorbent vessels, united by means of a spongy erectile tissue. Great confusion exists among anatomists in their descriptions of the papillæ of the tongue. Those concerned in the sense of taste may, however, all be included in two divisions:—1st, the *conical*, or *pyramidal*,—the finest sort being by some called *filiform*; and 2dly, the *fungiform*. The former are broader at the base than at the top, and are seen over the whole surface of the tongue, from the tip to the root. The latter, which are larger at the top than at the base and resemble the mushroom,—whence their name,—are spread about, here and there, upon the surface of the organ. These papillæ of taste must be distinguished from a third set, the *papillæ capitatæ*, which are mucous follicles, and of course accomplish a very different function.

All the nerves, that pass to the parts whose office it is to appreciate savours, must be considered to belong to the gustatory apparatus. These are the inferior maxillary, several branches of the superior, filaments from the spheno-palatine and naso palatine ganglions, the lingual branch of the fifth pair, the whole of the ninth pair or great hypo-glossus, and the glosso-pharyngeal. To which of these must be assigned the function of gustation we shall inquire presently.

Fig. 17.

a. Foramen of Morgagni.
b. Fungiform papillæ.
c. Conical papillæ.
d. Papillæ capitatæ.
e. Epiglottis.

Like the skin and mucous membranes in general, that of the tongue and mouth contains, in its substance, numerous mucous follicles, which secrete a fluid that lubricates the organ, and keeps it in the conditions best adapted for the accomplishment of its functions. Some of these are placed very conspicuously in the mucous membrane of the tongue. They are the *papillæ capitæ* of many anatomists, erroneously named, as they are not formed like the papillæ, and as we have said, execute a very different office. They are mucous follicles, and ought to be so called. They are situated near the base of the tongue, and the last perceptible rows anteriorly unite at an angle close to the *foramen cæcum* of Morgagni. (See Fig. 17.) The fluids, exhaled from the mucous membrane of the mouth, and the secretion of the different salivary glands likewise aid in gustation; but they are more concerned in mastication and insalivation, and will require notice under another head.

Of Savours.

Before proceeding to explain the physiology of gustation, it will be necessary to inquire briefly into the nature of bodies, connected with their sapidity, or, in other words, into *savours*, which are the cause of sapidity.

The ancients were of opinion, that the cause of sapidity is a peculiar principle, which, according to its combination with the constituents of bodies, gives rise to the various savours that are found to exist. This notion has long been abandoned; and chiefly, because we observe no general or common characters amongst sapid bodies, which ought to be expected if they were pervaded by the same principle; and because it is found, that bodies may be deprived of their sapidity by subjecting them to appropriate agents. Many of our culinary processes have been instituted for this purpose: the infusion of tea is indebted for all its attractions to the power we possess of separating, by boiling water, its savoury from its insipid portions. A savour must, therefore, be esteemed an integrant molecule of a body; not identical in all cases, but as heterogeneous in its nature as the impressions that are made upon the organ of taste.

When the notion was once entertained, that savour is an integrant molecule, sapidity was attempted to be explained by the shape of the molecule. It was said, for instance, that if the savour be sweet, the molecule must be round; if sharp, angular; and so forth. Sugar was said to possess a spherical,—acids, a pointed or angular molecule. We know, however, that substances, which resemble each other in the primitive shape of their crystal, impress the organ of taste very differently; and that solution which must destroy most, —if not all—of the influence from shape, induces no change in the savour.

Others have referred sapidity to a kind of chemical action between the molecules and the nervous fluid. This view has been suggested by the fact, that, as a general principle, sapid bodies, like chemical agents, act only when in a state of solution; that the same savours usually belong to bodies possessed of similar chemical properties as is exemplified by the sulphates and nitrates; and that, in the action of acids on the tongue and mouth, we witness a state of whiteness and constriction, indicative of a first degree of combination. All these circumstances, however, admit of a more philosophical explanation. There are unquestionably many substances, which do combine chemically,—not with a nervous fluid, of whose existence we know nothing,—but with the mucus of the mouth, and the sapidity resulting from such combination is appreciated by the nerves of taste; but there are many bodies, which are eminently sapid, and yet afford us instances of very feeble powers of chemical combination; nay, in numerous cases, we have not the least evidence that such powers are existent. Vegetable infusions or solutions afford us strong examples of this kind,—of which syrup may be taken as the most familiar. The effect of solution is easily intelligible; the particles of the sapid body are in this way separated, and come successively into contact with the gustatory organ; but we have reason to believe, that solution is not always requisite to appreciate sapidity. Metals have generally a peculiar taste, which has been denominated *metallic;* and this, even if the surface be carefully rubbed, so as to free it from oxide, which is more or less soluble. Birds, too, whose organs of taste are as dry as the corn they select from a mass of equally arid substances, are probably able to appreciate savours. The taste, produced by touching the wires of a galvanic pile with the tongue, has been offered as another instance of sapidity exhibited by dry bodies. This is, more probably, the effect of that chemical action on the fluids covering the mucous membrane of the tongue, which always follows such contact. Such chemical change must, however, be confined to these fluids, and when once produced, the nerve of taste is compelled to appreciate the savour developed in the same manner as it does, in cases of morbid alterations of the secretion of the mucous membrane, when, it is well known, that a body, possessing considerable and peculiar sapidity, may fail to impress the nerves altogether, or may do so inaccurately. The notion of any chemical combination with the nervous fluid must of course be discarded. There is not the slightest shadow of evidence in favour of the hypothesis. Yet the epithet *chemical* was once applied to this sense on the strength of it, in opposition to the senses of touch, vision, and audition, which were called *mechanical,* and supposed to be produced by vibration of their nerves.

The savours, met with in the three kingdoms of nature, are innumerable. Each body has its own, by which it is distinguished: but few instances occur in which any two can be said to be identical. This is the great source of difficulty, when we attempt to throw them into classes, as has been done by many physiologists. Of these classifications, the one by Linnæus is the best known. It will elucidate the unsatisfactory character of the whole: he divided sapid bodies, into *sicca, aquosa, viscosa, salsa, acida, styptica, dulcia, pinguia, amara, acria, et nauseosa.* He gives also examples of mixed savours—the *acido-acria, acido-amara, amaro-acria, amaro-acerba, amaro-dulcia, dulci-styptica, dulci-acida, dulci-acria,* and *acrivis-cida;* and remarks, that the majority are antitheses to each other, two and two, as the *dulcia* and *acria;* the *pinguia* and *styptica;* the *viscosa* and *salsa;* and the *aquosa* and *sicca.* Boerhaave again divides them into *primary* and *compound*; the former including the *sour, sweet, bitter, saline, acrid, alkaline, vinous, spirituous, aromatic,* and *acerb;*—the latter resulting from the union of some of the primary savours. There is, however, no accordance amongst physiologists regarding those that should be esteemed primary, and those that are secondary and compound; although the division appears to be fairly admissible. The *acerb,* for example—which is considered primary by Boerhaave—is by others, with more propriety, classed among the *secondary* or *compound,* and believed to consist of a combination of the acrid and acid. Still we understand sufficiently well the character of the *acid, acrid, bitter, acerb, sweet,* &c.: but when, in common language, we have to depict other savours, we are frequently compelled to take some well known substance as the standard of comparison.

According to Adelon, the only distinction, which we can make amongst them, is,—into the *agreeable* and *disagreeable*. Yet of the unsatisfactory nature of this classification he himself adduces numerous and obvious proofs. It can only, of course, be applicable to one animal species, often even to an individual only; and often again only to this individual, when in a given condition. Animals are known to feed upon substances, which are not only disagreeable but noxious to other species. The most poisonous plants in our soil have an insect which devours them greedily and with impunity: the southern planter is well aware, that this is the case with his tobacco, unless the operation of *worming* be performed in due season. The old adage, that "one man's meat is another man's poison," is metaphorically accurate. Each individual has, by organization or association, dislikes to particular articles of food, or shades of difference in his appreciation of tastes, which may be regarded peculiar; and in certain cases these peculiarities are signal and surprising.

Of the strange differences, in this respect, that occur in the same individual under different circumstances, we have a common and forcible instance in the pregnant female, who often has the most ardent desire for substances, which were previously perhaps repugnant to her, or at all events not relished. The sense, too, in certain diseases—especially of a sexual character, or connected with the state of the sexual functions—becomes remarkably depraved, so that substances, which can, in no way, be ranked as eatables, are greedily sought after. Only a shorttime ago, a young lady was under the care of the author, whose greatest *bonne bouche* was slate pencils. At other times we find, chalk, brick-dust, ashes, dirt, &c. obtaining the preference.

Habit, too, has considerable effect in our decisions regarding the agreeable. The Roman liquamen or garum, the most celebrated sauce of antiquity, was prepared from the half putrid intestines of fish; and one of the varieties of the Οπος Σιλφιον, or laserpitium, is supposed to have been the assafœtida. Even at this time, certain of the orientals are fond of the flavour of this nauseous substance. Putrid meat is the delight of some nations; and a rotten egg, especially if accompanied with the chick, is highly esteemed by the Siamese. In civilized countries, we find game, in a putrescent state, eaten as a luxury: this to those unaccustomed to it, requires a true education. The same may be said of the pickled olive, and of several cheeses —the *fromage de Gruyère*, for example—so much esteemed by the inhabitants of continental Europe.

Magendie asserts, that the distinction of savours into the agreeable and disagreeable is the most important, as bodies, whose taste appears agreeable to us, are generally useful in our nutrition; whilst those whose taste is disagreeable are commonly noxious. As a general rule this is true, but there are many signal exceptions to it.

Physiology of Taste.

The physiology of taste being so nearly allied to touch, as effected by the mucous membranes, it will not be necessary to repeat here the utility of the various layers of which the mucous membrane of the mouth consists. In order that taste may be satisfactorily executed, it is necessary that this membrane should be in a state of integrity; for if the cuticle simply be removed, gustation is not effected, and we experience the morbid sensation of pain. It is also indispensable, that the fluids, poured into the cavity of the mouth, should be in the necessary quantity, and possess the proper physical characteristics. We can farther appreciate the advantages of mastication and insalivation, by which solid bodies are divided into minute portions, dissolved where soluble, and brought successively in contact with the organ of taste. The gustatory nerves thus receive the impression, and by the same agents the impression is transmitted to the brain. These nerves go to the formation of the papillæ, which, we have seen, are situated in a spongy, erectile tissue. As in the sense of tact and touch, it is probable, that this erectile tissue is not passive during the exercise of taste; but that, by means of it, the papillæ assume a kind of erection. Magendie believes this view to be void of foundation; but Sir C. Bell has properly remarked, that if we take a pencil and a little vinegar, and touch, or even rub it strongly on the surface of the tongue, where these papillæ do not exist, the sensation of the presence of a cold liquid is alone experienced; but if we touch one of the papillæ with the point of the brush; and, at the same time, use a magnifying glass, it is seen to stand erect, and the acid taste is felt to pass, as it were, backward to the root of the tongue.

This experiment confirms the one with the point of the needle already referred to, in showing, that the parts of the tongue, which possess the power of receiving tactile impressions, are distinct from those concerned in gustation. The fine conical papillæ, by some called *filiform*, seated at the sides and tip of the tongue, appear to be the most exquisitely sensible.

Although the sense of taste is almost wholly accomplished by the membrane covering the tongue, the other parts, enumerated amongst the organs of taste, often participate in the function;—as the palate, lips, interior of the mouth, top of the pharynx, &c. We find, indeed, that certain bodies affect one part of the mouth, and others another. Acids, for example, act more especially upon the lips and teeth; acrid bodies, as mustard, on the pharynx. But we have still more direct evidence in those cases in which the tongue has been wanting. Roland, of Saumur, in a work published in 1630, under the pompous title '*Aglossostomographie*,' gives the case of a child, six years of age, who lost her tongue in small-pox and yet could speak, spit, chew, swallow and taste. De Jussieu exhibited to the *Académie des Sciences* of Paris, in 1718, a Portuguese girl, born without a tongue, who also possessed all these faculties. In a case mentioned by Berdot, and cited by Rudolphi, in which no part of the tongue existed, the individual could appreciate the bitterness of sal ammoniac, and the sweetness of sugar; and Blumenbach refers, in his comparative anatomy, to the case of a young man, who was born without a tongue, and yet, when blindfold, could distinguish between solutions of salt and aloes put upon the palate.

Certain bodies leave their taste in the mouth for a length of time after they have been swallowed. This *arrière-goût*—the *nachgeschmack* of the Germans—is sometimes felt in the whole mouth; at others, in a part only; and is probably owing to the papillæ having imbibed the savour,—for the substances producing this effect belong principally to the class of aromatics. This imbibition frequently prevents the savour of another substance from being duly appreciated; and, in the administration of nauseous drugs, we avail ourselves of the knowledge of the fact, either by giving an aromatic previously, so as to forestall the nauseous preparation, or, by combining powerful aromatics with it, which strongly impress the nerves of the papillæ, and produce a similar result.

There is a common experiment, which has formed the foundation of numerous wagers, and elucidates this subject, or at least demonstrates, that the effect produced upon the nerve by the special irritant continues, as in the case of the other senses, for some time after it has made its impression, so that the nerve becomes comparatively insensible, for a time, to the action of other sapid bodies. It consists in giving to a person—blindfold—brandy, rum, and gin, or any other spirituous liquors in rapid succession, and seeing, whether he can discriminate one from the other. A few contacts are sufficient to impregnate the nerve so completely with the impression, that all distinction becomes confounded.

It has been remarked, that numerous nerves are distributed to the organ of taste; the ninth pair, the lingual, and other branches of the fifth, and the glosso-pharyngeal. An interesting question arises—which of these is the nerve of taste; or are more than one, or the whole concerned? Of old, the lingual nerve of the fifth pair was universally considered to accomplish the function solely; the other nerves being looked upon as simple motors. Boerhaave and others assigned the office to the ninth pair, and considered the others to be motors. The filaments of the fifth pair have been described as being perceptible even into the papillæ; but others have denied that they can be so traced. Opinions have generally settled down upon the lingual branch of the fifth pair. Such is the view of Sir Charles Bell, who considers the *ninth pair*, which arises from the anterior column of the spinal marrow, as the nerve of motion for the tongue; the *lingual branch of the fifth*, a nerve having a posterior root, as the nerve of taste; and the *glosso-pharyngeal* as the nerve by which the tongue is associated with the pharynx in the function of deglutition. Bellingeri considers this nerve to give the complete organic and involuntary character to the tongue. In this it is aided by the branches of the fifth pair and of the pneumogastric. The hypoglossal he regards as the nerve of the voluntary motions of the organ for articulate speech and modulated sound in singing,—an inference, which has seemed to be confirmed by the fact, that in fishes (*pisces muti*) it is wanting. It is likewise maintained, that the fifth is the first encephalic nerve, which appears in the lower classes of animated nature, as the taste is the first of the special senses noticed in them; that, at first, the nerve consists only of the lingual branch; and farther, that its size, in animals, is generally in a ratio with that of the organs of taste and mastication.

Some experiments by Magendie would seem to settle the question definitively. On dividing the lingual branch of the fifth pair on animals, he found, that the tongue continued to move, but that they always lost the faculty of appreciating savours. In this case, however, the palate, gums, and internal surface of the cheeks preserved the faculty, because supplied with other branches of the fifth. But when the trunk of this nerve was cut, within the cranium, the power of recognizing savours was completely lost in every part of the mouth,—even in the case of the most acrid and caustic bodies. He found, too, that this loss of the sense occurred in all those, who had the fifth pair morbidly affected.

The fifth pair may then be considered as the parent trunk for the gustatory nerve: and not only is it the nerve for the special function, but it is, as we have seen, that of general sensibility. Anatomy and physiology would consequently lead to the belief, that the touch or general sensibility, and the taste—a function of special sensibility—are more nearly allied than any of the other senses; some of which, we shall find, have distinct nerves for the two functions; the fifth pair, however, always endowing the organs with general sensibility.

This distinction between the taste and the other senses has led M. De Blainville to suppose, that it is perhaps, neither sufficiently special, nor sufficiently limited in extent to have a separate nervous system: and therefore, that all the nerves of the tongue are equally inservient to the sense, as the different nerves of the skin, which proceed from numerous pairs, are equally inservient to touch or tact.

Regarding the uses of the sense of taste.—Its immediate function, as has been remarked, is to give the sensation of savours. This function, like the touch, is instinctive, requires no education, cannot be supplied by any of the other senses, and is accomplished as soon as the tongue has acquired the necessary degree of developement. To this it may be replied, that the very young infant is not readily affected by savours. In all cases, however, certain sapid bodies excite their usual impression: and, in the course of a few months, when the organ becomes completely developed, the sense acquires a high, and often an inconvenient degree of acuteness.

The mediate or auxiliary offices of gustation are few in number, and limited in extent. It does not afford much instruction to the mind. The chemist and mineralogist occasionally gain information regarding bodies by its agency; but it is never considered by the physiologist as worthy of the rank of an *intellectual* sense: on the contrary, it is classed with olfaction as *corporeal.*

To appreciate a savour accurately, the sapid substance must remain for some time in the mouth: when rapidly swallowed the impression is extremely feeble, and almost null. Of this fact we take advantage, when compelled to swallow any nauseous substance: whilst we retain a savory article long in the mouth, in order that we may extract all its sweets. How different, too, is the consent of the auxiliary organs under these two circumstances. Whilst a luscious body augments the secretion of the salivary glands—or causes the mouth "to water," as it has been called,—projecting the saliva, at times, to a distance of some feet from the mouth, and disposing every part to approach and mingle with it; a nauseous substance produces constriction of every secretory organ, and this effect extends even to the stomach itself, so that it will often reject the offending article, as soon as it reaches the cavity. We can thus understand how, *cæteris paribus*, an article, which is pleasing to the palate, may be more digestible than one which excites disgust, and *vice versa.*

Of the "consent of parts," exerted by the stomach on the organ of taste, we have a familiar illustration in the fact,—that whatever may be the *gout*, with which we commence a meal on a favourite article of diet, we find that the relish is blunted as the stomach becomes filled; and hence the Romans were in the habit of leaving the table once or twice during a meal, and, after having unloaded the stomach, of returning again to the charge—"*vomunt ut edant, edunt ut vomant.*"

Among animals we see great diversities in this sense. Whilst none possess the refined taste of man, there are many, which are capable, by taste or smell, of knowing those plants, that are nutritive, from those that are noxious to them; and it is very unusual for us to find that an animal has died from eating those which are unquestionable poisonous to it. Yet, as we have remarked, a substance, which is noxious to one, may be eaten with impunity by another: and, if we select animals, and place them in a field, containing plants, all of which are ranked by us as poisons, and which are poisonous to a majority of those animals, we find that not only has a selection been made by each animal of that which is innocuous to it, but that the substance has furnished nourishment to it, whilst to the other it would have proved fatal. All this must be dependent upon peculiar, and inappreciable organization.

The sense of taste is more than any other, under the influence of volition. It is provided with a muscular apparatus, by which it can be closed or opened at pleasure; and, in addition, it ordinarily requires the assistance of the upper extremity, to convey the sapid substance to the mouth. The sense can, therefore, be exercised either *passively* or *actively*; and, by cultivation, it is capable of being largely developed. The spirit taster to extensive commercial establishments exhibits the truth of this in a striking manner. He has, of course, in his vocation, not only to taste numerous samples, but to appreciate the age, strength, flavour, and other qualities of each: yet the practised individual is rarely wrong in his discrimination. With almost all, if not all these "tasters," the custom is to take a small quantity of the liquor into the mouth; throw it rapidly around that cavity, and then eject it. A portion in this way comes in contact with every part of the membrane, and of course impresses not only the lingual branch, but the other ramifications of the fifth pair.

The *gourmet* of the French—somewhat more elevated in the scale than our ordinary epicure—prides himself upon his discrimination of the nicest shades of difference and of excellence in the materials set before him. Many *gourmets* profess to be able to pronounce, by sipping a few drops of wine, the country whence it comes, and its age; and, according to Stelluti, can tell by the taste, whether birds, put upon the table, are domesticated or wild—male or female:—"*sapevano dire gustando li tordi s'erano domestici ò pur selvaggi, e se maschi ò pur femmine.*" Dr. Kitchener, indeed, asserts, that many epicures are capable of saying in what precise reach or stretch of the Thames the salmon on the table has been caught. Such acuteness of sense is by no means desirable. Doomed to meet, in his progress through life, with such a preponderance of what demands obtuseness rather than acuteness of feeling, the epicure must be liable to continual annoyances and discomforts, which the less *favoured* can never experience.

Sect III.—of the sense of smell, or olfaction.

The object of this sense is to appreciate the odorous properties of bodies. It differs from the last, in the circumstance of the body not coming into immediate contact. It is only necessary that an odorous emanation shall impinge upon the organ of sense. Still, it does not essentially vary in its physiology from the sense of taste.

Anatomy of the Organ of Smell.

The organ of smell is a mucous membrane, which lines the nasal cavities, and is called the *Schneiderian* or *pituitary*. It resembles that which covers the organ of taste, except that the nervous papillæ are still more delicate, to correspond with the greater tenuity of the body, that has to make the impression. The membrane lines the whole of the bony cavities called the *nasal fossæ*, which are constantly open anteriorly and posteriorly, to permit the air, which traverses them, to proceed to the lungs. The anterior aperture is covered by a kind of pent-house or capital, for the purpose of collecting the odorous particles. This capital is called the *nose*. The essential part of the organ is the pituitary or olfactory membrane—the other parts being superadded in animals to perfect the sense.

The bony portions of the nose are separated from each other by a bone called the *vomer*. This septum is extended, by means of cartilage, to the anterior extremity of the nose, so that the nasal fossæ are divided into like parts, which have no communication with each other, but open together posteriorly into the top of the pharynx.

Within each of the nares, are two *convoluted* or *turbinated bones*—generally called *ossa spongiosa vel turbinata*; and, by the French *cornets*. These are situated one above the other; the *superior* being formed of a plate of the ethmoid bone—the *inferior* a distinct bone. They divide the general cavity of each nostril into three *passages* or *meatus*, as exhibited in Fig. 18*, where figures 7 and 10 represent the superior and inferior spongy bones respectively, and 11 the vomer;—the three meatus being chiefly comprised between these bones. The *inferior* meatus is broad and long, the least oblique and the least tortuous; the *middle* is narrow, almost as long, but more extensive from above to below; and the *superior* is much shorter, more oblique and still narrower. The narrowness of these passages, in the living subject, is so great, that the slightest tumefaction of the pituitary membrane renders the passage of air through the nasal fossæ extremely difficult. This is the cause of the difficulty of breathing through the nose, that attends a "cold in the head."

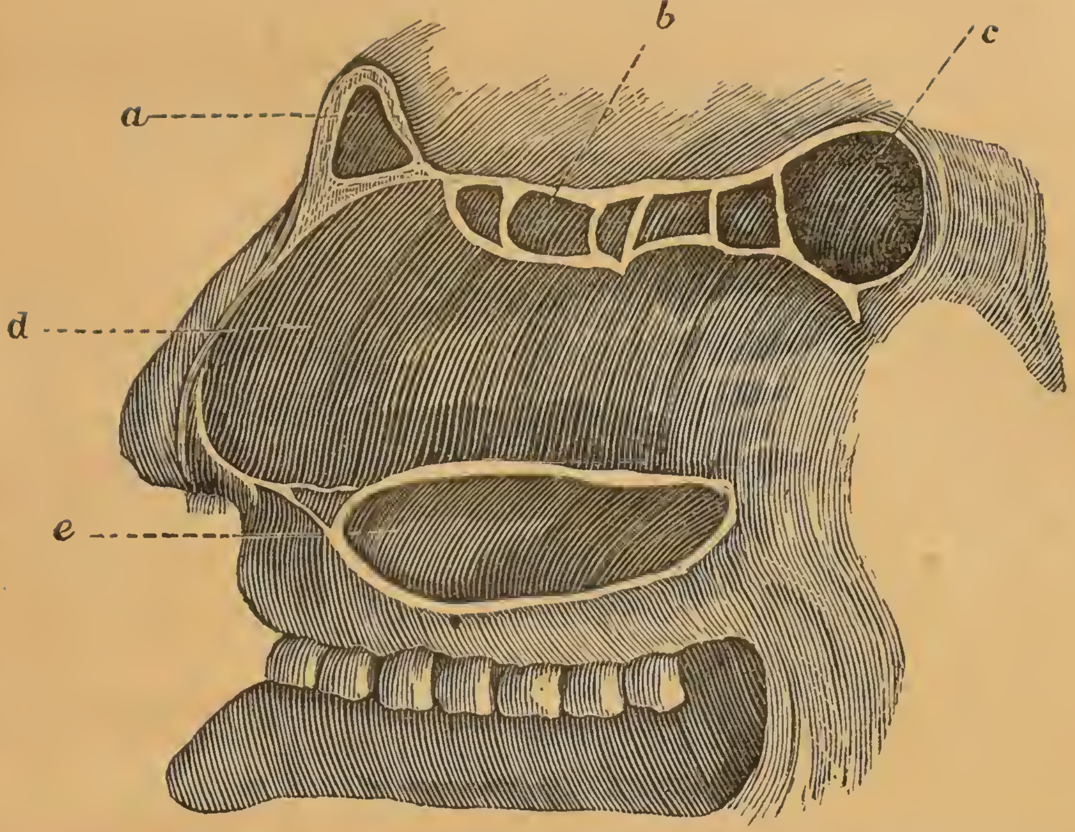
Fig. 18.

Transverse vertical section near the middle of the Nasal Fossæ, seen from behind.

1. Os frontis deprived of dura mater.
2. Do. covered by the dura mater.
5 5. Anterior part of the cribriform plate of the ethmoid bone.
6. Vertical plate of the ethmoid.
7. Os spongiosum superius.
8 8 8. Ethmoid cells.
9. Orbitar plate of the ethmoid bone.
10 10. Os spongiosum inferius.
11. Vomer.
12. Upper maxillary bone.
14 14. Anterior part of the maxillary sinus.
15 & 16. The fibrous and the mucous linings of the sinus.
18. Palatine arch.
20. Teeth.
26. Probe passed through the ductus ad nasum.
28. Orifice of the maxillary sinus.

Into the two upper passages cavities in certain bones open, which enlarge considerably the extent of the nasal fossæ. These are called *sinuses*, and consist of the *maxillary*, *palatine*, *frontal*, *sphenoidal* *ethmoidal*,—the last being sometimes termed *ethmoidal cells*.

Fig. 19.



a. Frontal sinus—b. Ethmoidal cells—c. Sphenoïdal sinus—d. Nasal fossæ—e. Maxillary sinus.

All the cavities are lined by the delicate membrane—the *Schneiderian* or *pituitary*—or by a prolongation of it. In the nasal fossæ, it augments the thickness of the turbinated bones. It resembles the mucous membranes in general in its composition, and adheres firmly to the bones and cartilages, which it covers. Its aspect is velvety, owing to a multitude of minute papillæ, and it receives a great number of vessels and nerves. The sinuses are lined by a prolongation, apparently, of the same membrane; differing, however, in some respects from the other. The whole of this membrane is the seat of the secretion of the *nasal mucus*, which, doubtless, performs a part in olfaction as important as the secretion from the mucous membrane of the mouth does in gustation.

The same nerve is not distributed over the whole of this membrane. In some parts, the *olfactory* or *first pair* can be traced; in others, we see only filaments of the fifth pair.

The first of these—the *olfactory* or *ethmoidal* nerves—have not always been regarded as the nerves of smell. Anciently, they were supposed to be canals for the passage of the pituita or phlegm, which was supposed to be secreted by the brain. At the present day, anatomists are doubtful only regarding their origin; some deriving them from the anterior lobe of the brain, others from the corpora striata, which have, in consequence, been called *thalami nervorum ethmoïdalium;* and others, again, with Gall, and with probability, referring them, like every other nerve of sense, to the medulla oblongata. Béclard affirms, that in a hydrocephalic patient, where a part of the brain had been destroyed by disease, he actually detected this origin.

The nerve proceeds directly forwards, (See Fig. 12,) until it reaches the upper surface of the cribriform plate of the ethmoid bone, when it divides into a number of filaments, which pass through the foramina in the plate, and attain the nasal fossæ, where they are dispersed on the upper and middle part of the Schneiderian membrane, but cannot be traced on the lower. Most anatomists are of opinion, that here they constitute, with vessels of exhalation and absorption, the papillæ; whilst others, as Scarpa, not having been able to trace them thither, have been of opinion, that the filaments interlace to constitute a kind of proper membrane.

Our means of observation cannot be considered sufficient to enable us to decide this question positively. In the case of the mouth, we have seen, that anatomy has not succeeded in following the nerve to its minute terminations; nor has it in the case of the olfactory or of any other nerve, if we except those of vision and audition, and in these we see the terminations but imperfectly.

The olfactory nerve has not been traced on the os spongiosum inferius, on the inner surface of the middle spongy bone, or in any of the sinuses.

Besides the first pair of nerves, the pituitary membrane receives several branches from the fifth encephalic pair; for example, the nasal twig of the ophthalmic branch of the fifth, and filaments from the frontal branch of the same, from the spheno-palatine ganglion, the palatine nerve, the vidian nerve, and from the anterior dental branch of the superior maxillary. One of these twigs enters the anterior naso-palatine canal, and, in its course to the roof of the mouth, passes through a small ganglion, which has been described by H. Cloquet under the name *naso-palatine*, and which he conceives to be the organ of sympathy between the senses of smell and taste.

The pituitary membrane is kept moist by the nasal mucus, as well as by the exhalation constantly taking place from it. It receives, likewise, the superfluous tears by means of the ductus ad nasum,—a duct passing from the inner canthus of the eye, and opening into the nasal fossæ below the lower spongy bone. The constant evaporation, which must take place from the membrane, owing to the passage of the air during respiration, requires that the secretion should be continuous and copious, otherwise the membrane would become dry.

The nasal fossæ communicate externally by means of the nostrils, the shape, size, and direction of which vary considerably, so as to give rise to the *aquiline*, *Roman*, *pug*, and other varieties of nose. At the extremity of the nostrils long hairs are situated—technically called *vibrissæ*—whose function, it is conceived, may be to sift, as it were, the air passing through, during respiration, and thus to prevent extraneous bodies from entering the fossæ. The nostrils are also capable of being expanded or contracted by appropriate muscles.

In this sense, we have a more clear separation between the physical and nervous part of the apparatus than in either of those we have considered;—the nose proper forming the essential physical portion; and the nerves of smell the organic or nervous.

Of Odours.

The comprehension of the physiology of olfaction will not be complete without an inquiry into *odours*, or those emanations from odorous bodies, which give character to them, and impress the organ of smell.

It was long maintained, as in the case of savours, that odours are dependent upon a peculiar principle, which, according to its particular combination with the constituents of bodies, gives rise to the various odours. To this principle the terms *aroma*, and *spiritus rector* have often been assigned; but the notion has been long abandoned, because no general or common characters were observable amongst odorous bodies, as ought to be expected, were they indebted for their odour to the same principle; and because, again, bodies can be deprived of their odour by exposing them to appropriate agents, as when we subject them to infusion and distillation.

Walther, a German physiologist, is of opinion, that an odorous body is only such by virtue of a vibratory motion, analogous to that made by a sonorous body. We have, however, the most satisfactory evidence, that there are special odorous, as there are special savory molecules. We can, for example, prevent an odorous body from impressing our olfactory nerves, by covering it with a glass receiver. Odours can likewise be separated, by infusion and by distillation. The fact, however, has been directly proved by an experiment of Berthollet. On putting a piece of camphor at the top of a tube, and filling the remainder of the tube with mercury he found, that, after a time, the mercury descended, the camphor had diminished in size, and the space above the metal was occupied by an odorous gas.

But what is the cause of the disengagement of these odorous molecules? By most writers on this subject it has been considered to be dependent upon the solvent action of caloric on the body. The opinion, that all bodies are odorous, is as old as Theophrastus, and it is one, which it is very difficult not to embrace, if we add—provided they are subjected to the appropriate agents for disengaging the odorous particles; and the probability is, that the reason we esteem particular bodies inodorous is, that our olfactory nerves are not organized with sufficient delicacy to enable us to distinguish their odorous properties. Heat assists the escape of odorous particles from a variety of bodies, and hence it has been maintained, that every body which is volatile must be odorous. Adelon asserts, that this is not the case, but it is difficult to accord with him. The fact of our not appreciating the odour is no proof of its non-existence. In truth, bodies that are inodorous to one animal or individual may be the contrary to another. In cases, too, in which the smell is morbidly acute, a substance may appear overwhelmingly odorous, which may not even impress the sense in healthy individuals. H. Cloquet refers to the case of a celebrated Parisian physician, who was subject to violent attacks of hemicrania or megrim, and who was dreadfully tormented, during one of the paroxysms, by the smell of copper, exhaled from a pin that had been dropped in the bed!

Caloric seems to be only one of the causes of the disengagement of odours. Some are retained by so feeble a degree of affinity, that they appear to be exhaled equally at all temperatures. Light influences their escape materially, in particular cases;—some plants giving off their fragrance during the day, others perfuming the air only at night. Dampness, too, in many cases, assists their escape—hence the fragrance of a garden after a summer's shower and the smell afforded by all argillaceous substances, when breathed upon—a fact, the knowledge of which is of considerable importance to the chemist.

Lastly, substances, which appear to us entirely devoid of odour, may exhale a strong one, when rubbed together. All these circumstances tend greatly to prove, that every substance is possessed of odorous qualities, provided we are aware of the precise mode for causing their emanation, although our olfactory nerves may not be sufficiently delicate to appreciate them.

Around the odorous body, the molecules, as they escape, must form an atmosphere, which, of course, will be denser the nearer it is to the body. These particles are diffused around,—not, probably, in the same manner as light or sound, but as one fluid mixes with another; and, when the air is still, it is conceived, that their strength will be inversely as the square of the distance from the substance exhaling them. There is a great difference, however, in odours with regard to their diffusibility in the atmosphere. Some extend to a great distance, whilst others are confined to a small compass. The odours of many flowers are so delicate as not to be appreciated, unless they are brought near the olfactory organs; whilst, according to Boyle that of cinnamon is experienced at sea, at the distance of twenty-five miles from Ceylon. Lord Valentia affirms, that he himself distinctly smelt the aromatic gale at nine leagues distance. Facts of this kind are employed by the natural philosopher to exhibit the excessive divisibility of matter. Scales, in which a few grains of musk have been weighed, have retained the smell for twenty years afterwards, although they must have been constantly exhaling odorous molecules during the whole of this period. Haller kept some papers, for more than forty years, which had been perfumed by a single grain of amber; and, at the end of that time, they did not appear to have lost any of their odour. That distinguished physiologist and mathematician calculated, that every inch of their surface had been impregnated by $\frac{1}{2691064000}$th of a grain of amber, and yet they had scented for 14,600 days a stratum of air at least a foot in thickness. But how much larger must these molecules be than those of light—provided we regard it as consisting of molecules—seeing that glass is capable of retaining the former, but suffers the other to penetrate it in every direction without obstacle!

The air is not the only vehicle for odours. It has been seen, that they adhere to solid bodies; and that, in many cases, they can be separated by aqueous or spirituous distillation. The art of the perfumer consists in fixing and preserving them in the most agreeable and convenient vehicles. Yet, it was at one time strenuously denied, that they could be conducted through water; and, as a natural consequence of this view, that fishes could smell. Duméril, for example, maintained, that odours, being essentially of a volatile or gaseous nature, cannot exist in fluids; and, moreover, that fishes have no proper olfactory organ;—that the part which is commonly considered as such, is their organ of taste. The opinion is now entertained by few. We have seen, that odours can be retained in fluids, and not many naturalists of the present day will be hardy enough to deny, that fishes have an organ or sense of smell. At all events, few anglers, who have used their oil of rhodium, or other attractive bait, will be disposed to give up the results of their experience, without stronger grounds than any that have been assigned by the advocates of that view of the subject.

When it was determined, that odours consist in special molecules, given off from bodies, it was attempted to explain their action on the pituitary membrane in the same manner as that of savours on the membrane of the tongue. It was conceived, for example, that the shape of the molecules of a pungent odour is pointed, that of an agreeable one, round. Others, again, were of opinion, that olfaction is owing to some chemical union between the odorous molecule and the nervous fluid, or between it and the nasal mucus. None, however, have attempted to specify the precise chemical composition, that renders a body odorous. The sensations are not the most favourable occasions for exhibiting chemical agency; and, in this particular sense, it is probably no farther concerned than in the sense of touch, and not so much as in that of taste. It is sufficient for the odorous particle—animal, vegetable, or mineral—to come in contact with the olfactory nerves, in order that the odour may be appreciated; and we may, in vain, look for chemical action in many of those animal and vegetable perfumes,—as musk, amber, camphor, vanilla, &c.—which astonish us by their intensity and diffusibility.

The same remarks, that were made on the classification of savours, are applicable to that of odours. They are not less numerous and varied; and each substance, as a general principle, has its own, by which it is distinguished. Numerous attempts have been made to group them, but all are unsatisfactory.

The classification, proposed by Linnæus, was—into *Odores aromatici*, as those of the flowers of the pink, bay leaves, &c.; *O. fragrantes*, as those of the lily, jessamine, &c.; *O. ambrosiaci*, as those of amber, musk, &c.; *O. alliacei*, as those of garlic, assafœtida, &c.; *O. hircini*, (like that of the goat,) as those of the *Orchis hircina*, *Chenopodium vulvaria*, &c.; *O. tetri*, or *repulsive* or *virous*, as those of the greater part of the family *solaneæ;* and lastly, *O. nauseosi*, as that of the flowers of the veratrum, &c. A simple glance at this division will exhibit its glaring imperfections. No two individuals could, in fact, agree to which of any two of the cognate classes a particular odour should be referred.

None of the other classifications, which have been proposed, are more satisfactory. Fourcroy divided them into the *extractive* or *mucous*, the *fugaceous oily*, the *volatile oily*, the *aromatic and acid*, and the *hydrosulphureous;*—Lorry into the *camphorated*, *narcotic*, *ethereal*, *volatile acid*, and *alkaline*.

The distinction into *animal*, *vegetable*, and *mineral*, is not more commendable. Musk is the product of an animal of the ruminant family, but the odour is not confined to this animal. It is contained in the civet, in the flesh of the crocodile, and in the musk-rat. Haller asserts, that his own perspiration smelt of it. It is met with, likewise, in the vegetable kingdom—in the *Erodium moschatum*, in the seeds of the *Abelmoschus*, the flowers of the *Rosa moschata*, and of the *Adoxa moschatellina*, and in some of the varieties of the melon and the pear; and, what is perhaps more surprising, in mineral substances;—as in certain preparations of gold, and in some earths of which tea-pots are formed in China and Japan.

The odour of garlic, again, is found not only in that vegetable, but in assafœtida; in arsenic, when thrown upon hot coals; and in the *Bufo pluvialis*, a species of toad.

In by far the majority of cases, we can only designate an odour by comparing it with that of some well known substance,—hence the epithets *musky*, *alliaceous*, *spermatic*, &c. Adelon asserts, that the sole classification, which can be adopted, is into the *agreeable* and *disagreeable*. But even the miserably imperfect division proposed by Haller is better than this: he made three classes—*Odores suaveolentes*, *O. medii*, and *O. fœtores*. The truth is that all the objections, made to the division of savours into the *agreeable* and *disagreeable*, are equally applicable to odours.

Assafœtida, we have seen, was employed by the ancients as a condiment; and although with us it has the name *devil's dung*, it is by many of the Asiatics called the *food of the gods*. We find, too, certain animals that are almost enravished by particular odours. The cat, for example, if the catmint—*Nepeta cataria*—or the root of the valerian—*Valeriana officinalis*—be placed in its way. These differences, like those in the appreciation of savours by animals, must be referred to minute and inappreciable organization.

Odours have been considered to be possessed of medicinal and even of poisonous properties. Some individuals, whose peculiarity of constitution renders them very liable to the action of ipecacuanha or jalap, will experience the emetic effects of the former, or the cathartic qualities of the latter, by merely smelling them for a short time, and the majority of individuals, by pounding jalap or rhubarb for a long period, will find themselves more or less affected. By smelling strong alcohol for a considerable time, intoxication may be induced, as not unfrequently happens to the spirit taster, who is young in his vocation. It has also been asserted, that the constant application of this sense to the discrimination of teas, in the English East India Company's warehouses, has laid the foundation for numerous head affections; but the report originated in prejudice or in accidental coincidences, and has not been found to be accurate.

In all these cases, in which we see medicinal or poisonous effects actually produced by substances inhaled through the nostrils, we cannot attempt to explain them, by the simple impression, made by the odorous particle, on the olfactory nerve. They must be accounted for by the circumstance of the minute particles of the medicinal or poisonous substance being diffused in the atmosphere and coming into contact with the mucous membranes, from which they are absorbed, and in this manner enter the circulation.

Odours have, likewise, been considered to possess nutritive properties; and this chiefly, perhaps, from the effect known to be produced by savory smells upon the appetite. It is not probable, that absorption can, in this case, occur to a sufficient extent to account for the apparent satiation. The fact can only be explained by the effect upon the nervous system, which influences the appetite materially, as we see in the operation of various mental emotions. The first impact of a nauseous odour, or even the view of a disgusting object, will frequently convert the keenest appetite, on the instant, into loathing. Yet, anciently, it was believed that life might be sustained for some time, by simply smelling nutritious substances. Democritus is said to have lived three days on the vapour of hot bread; and Bacon refers to a man, who supported an abstinence of several days by inhaling the odour of a mixture of aromatic and alliaceous herbs. Two hundred years ago, these notions were entertained to a great extent; and they afford the basis for the viaticum, suggested for travellers proceeding to the moon, according to the plan proposed by Dr. John Wilkins, Bishop of Chester.

This learned Prelate published a work in 1638, entitled, "*The discovery of a New World, or a Discourse tending to prove, that 'tis possible there may be another habitable World in the Moon, with a Discourse concerning the possibility of a passage thither.*" If we must needs feed upon something," he remarks, "why may not smells nourish us? Plutarch and Pliny, and divers other ancients, tell us of a nation in India, that lived only upon pleasing odours; and it is the common opinion of physicians, that these do strangely both strengthen and repair the spirits."

Fuller, a learned contemporary of the Bishop, affords an amusing instance of litigation, arising from this supposed nourishing character of odours. A poor man being very hungry, staid so long in a cook's shop, who was dishing up the meat, that his stomach was satisfied with only the smell thereof. The choleric cook demanded of him to pay for his breakfast; the poor man denied having had any; and the controversy was referred to the decision of the next man that should pass by, who chanced to be the most notorious idiot in the whole city; he, on the relation of the matter, determined that the poor man's money should be put betwixt two empty dishes, and that the cook should be recompensed with the jingling of the money, as he was satisfied with the smell of the cook's meat.

It need scarcely be said, that if the vapour from alimentary substances be capable, in any manner, of serving the purposes of nutrition, it can only be through the agency of the absorbents.

Physiology of Olfaction.

In order that the sense of smell be duly exercised, it is necessary, that the emanation from an odorous body shall not only impinge upon the pituitary membrane, but that it shall impinge with some degree of force. It must, in other words, be drawn in with the inspired air. Perrault and Lower found, that by making an opening into the trachea of animals, and thus preventing the inspired air from passing through the nasal fossæ, smell was not effected; and that dogs, which were the subjects of the experiment, readily ate food they had previously refused. These experiments were repeated by Professor Chaussier, and with like results. They explain, why we use considerable effort to draw in air loaded with an odour that is agreeable to us; and why, on the contrary, we arrest the respiration, or make it pass entirely through the mouth, when disagreeable. Still odours are occasionally so diffusible and expansible, that they will reach the olfactory membrane, and we are compelled to shut them off by calling in the aid of the upper extremity. The air being the ordinary medium for the conveyance of odorous molecules, we can understand why the organ of smell should form a part of the air passages.

The use of the nose itself is to direct the air, charged with odours, towards the upper part of the nasal fossæ. Its situation is well adapted for the reception of emanations from bodies beneath it, and its appropriate muscles allow the nostrils to be more or less expanded or contracted. The uses we have assigned to the nose are demonstrated by the fact, that they, whose noses are deformed—especially the flat-nosed—or whose nostrils are directed forwards, instead of downwards, have commonly the sense very feebly developed. Sir Charles Bell, indeed, asserts, "that the form of a man's nose has no relation to the extent or perfection of the organ of smelling;"—the seat of the sense lying "deep in the ethmoid bone." Yet, the loss of the nose, either by accident or disease, is found to completely destroy the sense; and, by no means the least advantage of the Taliacotian operation is the enjoyment afforded by the restoration of this corporeal sense. M. Béclard affirms, that an artificial nose, formed of paper or other appropriate material, is sufficient to restore it, so long as the substitute is attached. Of this we have had no experience, but no assertion of Béclard's is in need of confirmation.

The mode, in which olfaction is effected, appears to be as follows:—The inspired air, loaded with odorous particles, traverses the nasal fossæ; and, in this passage, comes in contact with the pituitary membrane, through the medium of the nasal mucus. The use of this mucus appears to be, not only to keep the organ properly lubricated, but to arrest the particles as they pass,—not by any chemical attraction, but in a purely mechanical manner. The olfactory nerves, being distributed on the membrane, receive the impression of the molecules as they impinge, and, in this manner, the sensation is accomplished.

The use of the different spongy or turbinated bones would seem to be to enlarge the olfactory surface. According to some, however, their office is, to form channels to direct the air towards the openings of the sinuses. The sinuses, themselves, afford subjects for physiological discussion. By many, they are considered, also, to add to the extent of olfactory surface: by others, to furnish the nasal mucus. No hesitation would be felt in pronouncing both the spongy bones and sinuses to be highly useful in olfaction, were it not, that the olfactory nerves, or first pair, have not been traced on the pituitary membrane covering the middle and inferior spongy bones, or on that, which lines the different sinuses;—that the sinuses are wanting in the infant, which, notwithstanding, can appreciate odours;—that they exist only in the mammalia;—and that experiments would seem to show, that the upper part of the olfactory organ is more particularly destined for the function, and that the sinuses, which, as well as the membrane covering the middle and lower spongy bones, are supplied by filaments from the fifth pair of nerves, are not sensible to odours.

That the upper part of the nasal fossæ is the great seat of smell, is proved by the facts referred to regarding the uses of the nose. Dessault, too, mentions the case of a young female, who had a fistula in the frontal sinuses, and who could not perceive an odorous substance, when presented at the orifice of the fistula, because there was no communication with the proper portion of the nasal fossæ, even although she was capable of breathing through the opening. Deschamps, the younger, also relates a case of a man, who had a fistula of the frontal sinus, through which ether might be injected without being appreciated, provided all communication had been previously cut off between the sinus, and the upper part of the nasal fossæ; but if this precaution had not been taken, the sense was more vivid, when the odours passed through the fistulous opening, than when they reached the organ by the ordinary channel.

Professor Richerand, again, found that highly odoriferous injections, thrown through a fistulous opening into the maxillary sinus or antrum of Highmore, produced no olfactory sensation whatever.

All these facts would seem to lead to the belief, that the upper part of the nasal fossæ, on which the first pair or olfactory nerves are distributed, is the chief seat of olfaction, and that the inferior portions of these fossæ, as well as the different sinuses communicating with them, are not primarily concerned in the function; but, doubtless, offer secondary advantages of no little importance.

This conclusion would, however, seem to admit, what is not by any means universally admitted, that the olfactory nerve is the sole or chief nerve of smell. Especially difficult is it to embrace this view, and not to believe that the spongy bones and sinuses, on which the fifth pair are distributed, are agents in perfecting the sense, when we find them largely developed in animals that possess unusual delicacy of smell, as in the dog and elephant. It has already been remarked, that the ancients believed the olfactory nerves to be canals for conveying away the pituita or phlegm from the brain. Diemerbroeck, in 1672, maintained this opinion. At the early part of the last century, however, the olfactory was supposed to be the proper nerve of smell, and this opinion prevailed, with scarcely a dissentient voice, until within the last few years. Inspection of the origin and distribution of this nerve seems to indicate it as admirably adapted for a nerve of special sensibility connected with smell. It is largely developed in animals in proportion to their acuteness of smell, and is distributed on the very part of the pituitary membrane to which it is necessary to direct air, loaded with odorous emanations, in order that they may be fully appreciated. Magendie has, however, endeavoured to show, by experiment, that the sense of smell is in no wise, or but little, dependent upon the olfactory nerves, but upon the branches of the fifth pair. Prior to the institution of his experiments, he had observed with astonishment, that after he had removed the cerebral hemispheres with the olfactory nerves of animals, they still preserved this faculty. He had noticed, too, that the sense had continued in some lunatics, who had fallen into a state of stupor, and in whom the substance of the brain appeared, on dissection, greatly disorganized. These facts induced him to expose the olfactory nerves on living animals, and to experiment upon them. In the course of his experiments he found, in the first place, that the nerves were insensible to puncture, pressure, and to the contact of the most odorous substances. He afterwards satisfied himself, that after their division, the pituitary membrane not only preserved its general sensibility; appreciated the contact of bodies, but that it continued to feel strong odours, those of ammonia, acetic acid, oil of lavender, Dippel's oil, &c. On the other hand, having divided the fifth pair of nerves within the cranium, and left the olfactory nerves untouched, he remarked, that the pituitary membrane had lost its general sensibility; was no longer sensible to contact of any kind; and that it had lost the power of appreciating odours.

From these experiments, he considered himself justified in inferring, that the olfactory nerve does not preside over the general sensibility of the nose; that it has, at the most, but a special sensibility as concerns odours; and that if the olfactory nerve be the nerve of smell, it at least requires the influence of the fifth pair, in order that it may act: lastly, he asks, may not the general and special sensibility be comprised in the same nerve in the sense of smell, as they are in that of taste;—in the fifth pair?

These experiments are highly interesting; but they do not entirely establish, that the fifth pair is *the* olfactory nerve. The numerous facts, already mentioned, attract us irresistibly to the first pair, or *olfactory*, as they have been exclusively called. It has been already remarked, that the fifth is concerned in all the facial senses; that it conveys to them general sensibility, or feeling; and that some of them are unquestionably supplied with nerves of special sensibility;—the eye, for example, with the optic nerve, and the ear with the auditory; but that neither one nor the other can exert its special function, without the integrity—the presidency—of the fifth pair. The olfactory nerve is probably in this category,—is the nerve of special sensibility. It is true, that in the experiments of Magendie the animal appeared to be affected by odorous substances, after the division of the first pair; but a source of fallacy might exist here, in discriminating accurately between the general and special sensibility. Some of the substances employed were better adapted for eliciting the former than the latter;—ammonia and acetic acid, for example.

The immediate function of the sense of smell is to appreciate odours. In this it cannot be supplied by any other sense. The function is instinctive; requires no education; and is exerted as soon as the parts have attained the necessary degree of developement. In many respects this sense is intimately connected with that of taste, and the impressions made upon each are frequently confounded. In the nutritive function, the smell serves as a kind of advanced guard or sentinel to the taste, and warns us of the disagreeable or agreeable nature of the aliment; but if a substance, that is repugnant to the smell, be agreeable to the taste, the smell soon loses its aversion, or at least becomes less disagreeably impressed. The smell is not, however, so useful to man as a sentinel to the taste, as it is to animals: there are many bodies,—those containing prussic acid for example,—which are extremely pleasing by the odours they exhale, and yet are most noxious to the human frame. In the animal kingdom, this sense is greatly depended upon, and is rarely a fallacious guide. It enables animals to make the proper selection of the noxious from the innocent—the alimentary from that which is devoid of nutriment—the agreeable from the disagreeable; and this power appears to be instinctive or dependent upon inappreciable varieties of structure in the olfactory organs.

As an intellectual sense, the smell is not entitled to a higher rank than the taste. Its mediate functions are very limited. It enables the chemist, the mineralogist, and the perfumer to discriminate bodies from each other. We can, likewise, form a slight—but only a slight—idea by it, regarding the distance and direction of bodies, owing to the greater intensity of odours near an odorous body, than at a distance from it. Under ordinary circumstances, the information of this kind, which we derive by olfaction, is inconsiderable; but in the blind, and in the savage, who are accustomed to exercise all their external senses more than the civilized individual, the sphere of utility and accuracy of this sense is largely augmented. Of this we shall have to speak presently. We find it, too, surprisingly developed in some animals; in which it is considered, by the eloquent Buffon, as an eye that sees objects not only where they are, but where they have been,—as an organ of gustation, by which the animal tastes not only what it can touch and seize, but even what is remote, and cannot be attained; and he esteems it a universal organ of sensation, by which animals are soonest and most frequently impressed, and by which they act and determine, and recognize whatever is in accordance with, or in opposition to their nature. The hound, amongst quadrupeds, affords us a familiar example of the extreme delicacy of this sense. For hours after the passage of game, it is capable of detecting the traces; and the bloodhound can be trained to indicate the human footsteps with unerring certainty.

Until of late it was almost universally believed, that many of the birds of prey possess an astonishingly acute sense of smell. Humboldt relates, that in Peru, Quito, and in the Province of Popayan, when they are desirous of taking the gigantic Condor—the *Vultur gryphus*, of Linnæus—they kill a cow, or horse, and in a short time, the odour of the dead animal attracts those birds in numbers, and in places where they were scarcely known to exist. It is asserted, too, that vultures went from Asia to the field of battle at Pharsalia, a distance of several hundred miles, attracted thither by the smell of the killed! Pliny, however, exceeds almost all his contemporaries in his assertions on this matter. He affirms, that the vulture and the raven have the sense of smell so delicate, that they can foretell the death of a man three days beforehand, and, in order not to lose their prey, they arrive upon the spot the night before his dissolution! The *turkey buzzard* of the United States is a bird of this class, and it is surprising to see how soon they collect from immense distances after an animal has died in the forests. The recent observations and experiments of the celebrated ornithologist—Audubon—have shown, that this bird possesses the sense of smell in a less degree than the carnivorous quadruped. Audubon stuffed the skin of a deer with hay, and after the whole had become perfectly dry and hard, he placed it in an open field on its back, and in the attitude of a dead animal. In the course of a few minutes a vulture was observed flying towards it. It alighted near, and began to attack it, tearing open the seams, and pulling out the hay; but finding that it could obtain nothing there congenial to its taste, it took to flight. It was found, too, that when animals, in an advanced state of putridity, were lightly covered over so as to prevent the vultures from seeing them, they remained undisturbed, and undiscovered, although the birds repeatedly flew over them. In some other experiments it was found, that birds of prey were even attracted by well executed representations of dead animals, painted on canvass and exposed in the fields,—and in other experiments, that young vultures, enclosed in a cage, exhibited no tokens of their perceiving food, when it could not be seen by them, however near to them it was brought.

As the organ of smell, in all animals that respire air, is situated at the entrance of the organs of respiration, it is probable that its seat, in insects, is in the mouths of the air tubes. This sense appears to guide them to the proper kinds of food, and to the execution of most of the few offices they have to perform during their transient existence. Occasionally, however, they are deceived by the resemblance between the odours of substances very different in other qualities. Some plants, for example, emit a cadaverous odour, similar to putrid flesh, by which the flesh-fly is attracted, and led to deposit its ova in parts that can furnish no food to the future progeny.

As regards the extent of the organ of smell, man is undoubtedly worse situated than most animals, and all things being, in other respects, equal, it may be fair to presume, that those, in which the olfactory membrane is most extensive, possess the sense of smell most exquisitely. It is curious, however, that animals, which have the sense of smell in the highest degree, are those that feed on the most fetid substances. The dog, for instance, riots in putridity; and the birds of prey, to which reference has been made, have similar enjoyment. The turkey buzzard of the United States is so fetid and loathsome, that his captors are generally glad to loosen him from bondage; and it is affirmed, that if his ordinary fetor is insufficient to produce his release, he affords an irresistible incentive, by ejecting the putrid contents of his stomach upon his possessor.

One inference may, perhaps, be drawn from this *penchant* of animals with the most exquisite olfactories for putrid substances;—that the taste of the epicure for game, kept until it has attained the requisite *fumet*, is not so *unnatural* as it might at first sight appear.

Like the senses already described, that of smell is, to a certain extent, under the influence of volition;—in other words, it can be exerted *actively*, and *passively*. Its active exercise—as when we smell any substance to enjoy its sweets or to test its odorous qualities—generally requires prehension; the proper direction of the head towards the object; and more or less contraction of certain muscles of the alæ nasi. Doubtless, here again, the papillæ are capable of being erected under the attention, as in the senses of taste and touch. On the other hand, we can throw obstacles in the way of the reception of disagreeable odours; and, if necessary, can prevent their ingress altogether, by compressing the nostrils with the upper extremity.

Lastly, like the other senses, the smell is capable of great improvement by education. The perfumer arrives, by habit, at an accurate discrimination of the nicest shades of odours; and the chemist and the apothecary employ it constantly to aid them in distinguishing bodies from each other; and in pointing out the changes, that take place in them, under the influence of heat, light, moisture, &c. In this way it becomes a useful chemical test. The effect of education is likewise shown, by the difference between a dog, kept regularly accustomed to the chase, and one that has not been trained. For the same reason, in man, the sense is more exquisite in the savage than in the civilized state. In the latter, he can have recourse to a variety of means for distinguishing the properties of bodies, and hence he has less occasion for acuteness of smell than in the former; whilst, again, in the civilized state, numbers destroy the sense, in order to procure pleasure. The use of snuff is one of the most common of these destructive influences.

Of the acuteness of the sense of smell in the savage, we have an example, on the authority of Humboldt: he affirms, that the Peruvian Indians in the middle of the night, can distinguish the different races by their smell,—whether they are European, American Indian, or negro.

To the same cause must be ascribed the delicacy of olfaction, generally observed in the blind. The boy Mitchell, who was born blind and deaf, and whose case will have to be detailed at length hereafter, was able to distinguish the entrance of a stranger into the room by the smell alone. A gentleman, blind from birth, from some unaccountable impression of dread or antipathy, could never endure the presence of a cat in the apartment. One day, in company, he suddenly leaped up, got upon an elevated seat, and exclaimed that there was a cat in the room, begging them to remove it. It was in vain, that the company, after careful inspection, assured him he was under an illusion. He persisted in his assertion and in his state of agitation; when, on opening the door of a small closet in the room, it was found, that a cat had been accidently shut up in it.

SECT. IV.—OF THE SENSE OF HEARING OR AUDITION.

Audition makes known to us the peculiar vibrations of sonorous bodies, which constitute *sounds*. It differs from the senses, which have already been described, in the fact, that contact is not required between the organ of sense and the sonorous body; or between the organ and any emanation from the body. It is, however, a variety of touch, but produced by a medium, acted upon by the vibratory body.

Anatomy of the Organ of Hearing.

The auditory apparatus is a subject of intricate study to the young anatomist; and, unfortunately, when he has become acquainted with the numerous minute portions, to which distinct and difficult appellations have been appropriated, he has here, as in many other cases, attained a mere tedious detail of names, without having added to his stock of philosophical information. Happily, it is not necessary for our purpose to go thus minutely into the description of the organ of hearing. According to the plan, hitherto pursued, allusion will be made to those portions of it only, which concern the physiological inquirer.

In the ear, as well as in the eye, we have the distinction between the physical and nervous portions of the organs more clearly exhibited than in the skin, mouth, or nose. The nervous portion is situated deeply within the organ; and the parts, between it and the exterior, act physically on the sonorous vibrations, in the case of the ear; and on the light, in that of the eye.

The organs of the senses, hitherto considered, are symmetrical. Those of audition are two in number, distinct but harmonious, and situated at the sides of the head, in a part of the temporal bone, generally called from its hardness, the *pars petrosa*, and by the French anatomists regarded as a distinct bone, under the similar appellation of *Le Rocher*. This bone is seated at the base of the skull, so that the internal parts of the auditory organ are deeply and securely lodged.

For facility of description, the ear may be divided into three distinct portions:—1, the *external ear*, or that exterior to the membrana tympani; 2, the *middle ear*—the space contained between the membrana tympani and the internal ear; and 3, the *internal ear* itself, in which the auditory nerve is distributed.

1. The *external ear*.—This portion of the auditory apparatus is commonly looked upon as an acoustic instrument, for collecting the sonorous rays or vibrations, and directing them, in a concentrated state, to the parts within. It is composed of the *pavilion*, and *meatus auditorius externus*.

Fig. 20.

1. The pavilion.
2. Meatus auditorius externus.
3. Membrana tympani,
4. Malleus,
5. Incus.
6. Stapes, Os orbiculare between the incus and stapes.

} small bones of the ear.

7. Cavity of the tympanum.
8. Eustachian tube.
9. Meatus auditorius internus.
10. 11. 12. The labyrinth.
10. Vestibule.
11. 11. 11. Semicircular canals.
12. The cochlea.
13. Stapedius muscle.

The *pavilion* varies in size and position in different individuals. It is the fibro-cartilaginous thin, and, expanded portion, which is an appendage, as it were, to the head. It is irregular on its anterior surface; presenting several eminences and depressions. The eminences are five in number, and have been called, by anatomists, the *helix*, *ant-helix*, the *tragus*, *anti-tragus*, and the *lobe*.

The *helix* forms the rim of the pavilion: the *tragus* is the small nipple-like projection on the facial side of the meatus auditorius; the *anti-tragus* is the projection opposite to this,—forming the lower portion of the *ant-helix;* and the *lobule* is the fatty, pendulous portion, to which ear-rings are attached. The depressions are three in number—the *groove of the helix* or *cavitas innominata; the fossa navicularis* or *scapha;* and the *concha*. The name of the first sufficiently indicates its situation; the second is nearer the meatus auditorius; and the concha is the expanded portion, which joins the commencement of the meatus, and is bounded by the ant-helix, tragus, and anti-tragus.

The pavilion is supple and elastic; and, beneath the skin, are numerous sebaceous follicles, which are distinctly perceptible, and give to the skin its polish, and probably a portion of its suppleness.

On the different eminences, some muscular fibres are perceptible, which it is not necessary for our purpose to distinguish; for in man at least they are only *vestiges*—as the French term them—to indicate the uniform plan, which appears to have prevailed in the formation of the vertebrated animals; if they have any office, it must be extremely unimportant.

Numerous vascular and nervous ramifications are distributed on the pavilion. It is attached to the head by different ligaments, called—from their situation or attachments—*zygomato-auricular* or *anterior auricular:—temporo-auricular* or *superior auricular*, and *mastoido-auricular* or *posterior auricular;* all of which terminate on the convex part of the concha. Three muscles, in animals at least, are attached to the ear, so as to move the pavilion. These occupy the same position as the ligaments described, and have similar names. In man, these again are mere vestiges; but in many animals—in the horse, for example—they are largely developed, and are capable of moving the pavilion in various directions.

The *meatus auditorius externus* extends from the inner extremity of the concha to the membrana tympan. In the adult it is about an inch long; narrower in its middle than at the extremities; longer inferiorly than superiorly, owing to the obliquity of the membrana tympani; and slightly curved upwards about its middle. The outer orifice is furnished with down or hairs, like the orifices of certain other canals. The meatus is partly osseous, for the space of half an inch, and penetrates the temporal bone. More externally it is formed of fibro-cartilage,—a prolongation of that of the concha. It is lined by an extension of the skin, which becomes gradually thinner as it proceeds inwards, and is ultimately reflected over the outer surface of the membrana tympani. Beneath this skin, numerous sebaceous follicles are situated, which secrete the bitter humour, called *cerumen.* This humour occasionally becomes inspissated; obstructs the canal; prevents the sonorous vibrations from reaching the membrana tympani, and is thus the cause of deafness. Softening the cerumen, by means of warm water or oil dropped into the meatus, and then removing it by means of the syringe, restores the hearing.

The portion, then, of the auditory apparatus—which we have arbitrarily termed the *external ear*—is a complete *cul-de-sac*, formed by a prolongation of the common integument. There is no opening communicating with the next portion—the middle ear—the membrana tympani, with its dermoid envelopes, forming at once the medium of union and of separation between the two. A knowledge of this fact would somewhat diminish the alarm, in cases where insects or other extraneous bodies get into the meatus auditorius. The pain is excruciating, owing to the great general sensibility of this portion of the auditory apparatus; but, generally, the chief dread entertained is, that the irritating substance may pass into the head. It cannot, of course, proceed farther than the membrana tympani: and even were it able to clear this obstacle, insuperable impediments exist to its farther progress.

2. The *middle ear* includes the cavity of the tympanum, the small bones contained in the cavity, the mastoid cells, Eustachian tube, &c. Like the last, it belongs to the physical portion of the ear.

The *cavity of the tympanum*, or *drum of the ear*, has the shape of a portion of an irregular cylinder. Its name is not, indeed, inappropriate. It has some resemblance to a drum, not only in form, but, as will be seen, in function likewise. The outer extremity of this cylinder is closed, like the drum, by the membrane already referred to—the *membrana tympani*. This membrane is not situated vertically in the meatus, but obliquely downwards and inwards, so that the cavity is broader above than below. It is very thin and transparent, and consists of three layers,—the outermost formed by the membrane lining the meatus auditorius externus; the most internal belonging to the membrane of the cavity of the tympanum; and the middle being the membrane proper. On its inner side is distributed the nerve, called *chorda tympani*, and its centre affords attachment to one extremity of the chain of small bones,—to the handle of the *malleus*.

The proper tissue of the membrana tympani is dry, and it is generally esteemed to be devoid of fibres, vessels, and nerves. Sir Everard Home, however, in the *Philosophical Transactions*, for the year 1800, and in the third volume of his *Lectures on Comparative Anatomy*—asserts, that the membrane is muscular; that its fibres run from the circumference towards the centre, and are attached to the malleus; and that if the membrane of the human ear be completely exposed, on both sides, by removing the contiguous parts, and the cuticular covering be washed off from its external surface, placing it in a clear light, the radiated direction of its fibres may be easily detected. This fibrous arrangement, Sir Everard conceives to be muscular, and on this he founds some ingenious speculations, to be hereafter noticed, regarding the appreciation of sounds. The discovery of a fibrous structure would, however, by no means prove, that the membrane is capable of contracting; or that it is formed of muscular tissue. Many of the ligaments, which consist of gelatine, and are consequently not contractile like muscles, are distinctly fibrous in their arrangement. The same may be said of the tendons, whose utility, as conductors of the force developed by the muscle, would be materially interfered with, were they possessed of the same degree of contractility.

Again, Ruysch, Sir Everard Home, and Sir Charles Bell affirm, that the membrana tympani is very vascular,—Sir Everard asserting, that the vessels, in their distribution, resemble those of the iris, and are nearly half as numerous;—their general direction being from the circumference to the handle of the malleus. It is not easy to account for this discrepancy amongst anatomists. A part of it is probably referable to some having directed their attention to the membrane proper; others to the membrane with its dermoid coverings, which are highly vascular.

The inner extremity of the drum is partly osseous, partly membranous. Nearly opposite the centre of the membrana tympani is the *foramen ovale* or *vestibulare*, called also *fenestra ovalis* or *vestibularis*, situated vertically, and forming a communication between the middle and the internal ear. It is closed by a membrane, consisting, like the membrana tympani, of three layers, to which is attached the base of the stapes,—the other extremity of the chain that stretches across the cavity. Immediately below the foramen ovale is the bony projection, called the *promontory;* and beneath this again, a second opening, called the *foramen rotundum* or *cochleare* or *fenestra rotunda* or *cochlearis*, which forms a communication between the middle ear and the external scala of the cochlea. This foramen is closed by a membrane, similar to that of the foramen ovale; but not, like it, parallel, or nearly so, to that of the tympanum, —being situated obliquely. There is no communication by a chain of bones between it and the membrana tympani.

These *small bones* or *ossicles* are four in number, so connected with each other as to form a bent lever; one extremity of which is attached to the tympanic surface of the membrana tympani,—the other to the membrane of the foramen ovale. These bones are usually termed, from their shape—beginning with the most external, and following their order—*malleus*, *incus*, *os orbiculare*, and *stapes*. A small muscular apparatus,—consisting of three muscles, the *anterior muscle of the malleus;* the *internal muscle of the same bone;* and the *muscle of the stapes*,—is attached to the chain, which it can stretch or relax; and of course it produces a similar effect upon the membranes to which the chain is attached. They are animated by branches of the portio dura, or facial nerve, which is itself not a nerve of sensibility, but of motion; yet probably acquires this function by its union with the vidian twig of the fifth pair, in its passage through the aqueduct of Fallopius. It is this nerve which furnishes the chorda tympani. Bellingeri thinks, that the fifth pair regulates altogether the involuntary motions of the internal ear.

At the anterior and inferior part of the cavity is the tympanic extremity of a canal, through which the drum receives the air it contains. This canal, called the *Eustachian tube*, is about two inches long, and proceeds obliquely forwards and inward, to the lateral and superior part of the pharynx, into which it opens behind the posterior nares. It is partly osseous, partly fibro-cartilaginous, and membranous; and, towards its pharyngeal extremity, it expands, terminating by an oval aperture, resembling a cleft. Throughout its course it is lined by a mucous membrane, which appears to be a prolongation of that of the nasal fossæ, and it is capable of being more or less contracted and expanded by the muscles, which compose and move the velum palati.

The cavity of the tympanum likewise communicates, by a short and ragged canal, with numerous cells contained in the mastoid process. These cells open into each other, and vary in number, size, and arrangement in different individuals, and animals. They are called the *mastoid cells.*

The cavity is larger in those animals, whose sense of hearing is most acute. In man, it is about a quarter of an inch deep, and half an inch broad. It is lined by a prolongation of the same membrane, as that which lines the Eustachian tube This membrane, as we have seen, covers the membrana tympani, and the membranes of the foramen ovale, and foramen rotundum. It likewise lines the mastoid cells, and is reflected over the small bones.

The middle ear does not exist in every animal endowed with hearing. It does not begin to appear lower in the scale than in reptiles; and is by no means equally complex in all. Frequently, the chain of bones is entirely wanting; and, at other times, we find one bone only.

3. The *internal ear* or *labyrinth* is the most important part of the apparatus. It consists of several irregular cavities in the pars petrosa of the temporal bone, in which the nerve of audition is distributed. It is, consequently, in this portion, that the physical part of audition terminates, and the nervous begins. The labyrinth comprises the *vestibule*, *semicircular canals*, and *cochlea.*

The *vestibule*—as its name imports—is the hall, that communicates with all the other cavities of the labyrinth. It would appear to be the most essential part of the organ, as it often exists alone. At its inner surface are numerous small foramina, which communicate with the bottom of the meatus auditorius internus, and through which the filaments of the auditory nerve reach the labyrinth. Externally, it communicates with the cavity of the tympanum by the foramen ovale. Posteriorly, it opens into the semicircular canals by five foramina; and, anteriorly, by a single foramen, into the internal scala of the cochlea. There is, also, posteriorly and inferiorly, near the common orifice of the two vertical semicircular canals, the opening of a small, bony duct, which terminates internally at the posterior surface of the petrous portion of the temporal bone. This duct is called the *aquæductus vestibuli.*

The *semicircular canals* are three in number, and occupy the hinder part of the labyrinth. They are called *superior vertical*, *posterior vertical*, and *horizontal.* They are cylindrical cavities, curved semicircularly, and are more expanded at their vestibular origin, which has been therefore called *ampulla.* They are constituted of a plate of bone, situated in the spongy tissue of the pars petrosa, and all of them communicate with the vestibule.

The *cochlea* is the most anterior portion of the labyrinth. It is so called in consequence of its resemblance—in man and in the mammalia—to a snail's shell; hence, also, its French and German names, *limaçon* and schneke. It is the most intricate part of the organ of hearing, and does not, by any means, admit of easy description. It is a conoidal canal, spirally convoluted, making two turns upon itself and resting on a bony nucleus or pillar, called *modiolus*. The base of the nucleus is concave; corresponds to the bottom of the meatus auditorius internus, and is pierced by small foramina, through which the filaments of the auditory nerve reach the cochlea.

The spiral canal is divided, in its whole length, by a partition, half osseous and half membranous, called the *lamina spiralis:* so that two distinct tubes are thus formed. These are the *scalæ of the cochlea.* At the apex of the cochlea they run into each other: but, at the base, the one turns into the vestibule, and is hence called the *superior* or *vestibular* or *internal scala;* the other communicates with the cavity of the tympanum by the foramen rotundum, and is called the *inferior*, *tympanic*, or *external scala*. At this scala, near the foramen rotundum, a bony canal begins, which proceeds towards the posterior surface of the pars petrosa on which it opens. It is the *aquæductus cochleæ.*

The cochlea does not exist in all animals that hear. It is not, therefore, of essential importance. It varies, too, greatly, in complication, in different animals. In birds, whose hearing is extremely delicate, it merely consists of a short, hollow, bony process, divided into two scalæ, but without any spiral arrangement. In reptiles, the cochlea is still more imperfect; and in many species it can scarcely be said to exist. In fishes there is no trace of it.

The different cavities of the internal ear are lined by an extremely delicate membrane. In many animals this membrane alone exists without any bony parietes. It exhales at its inner surface a limpid fluid, called the *liquor* or *lymph* of Cotugno or Cotunnius and *vitrine auditive*, which, under particular circumstances, can reflow into the aquæductus vestibuli and aquæductus cochleæ. This fluid is contained in all the cavities of the internal ear.

It is in these, likewise, that the *auditory* or *acoustic nerve* is distributed. This nerve is the *portio mollis* of the seventh pair of most anatomists. It arises, like the other nerves of the senses, from the medulla oblongata, and near the anterior paries of the fourth ventricle. From thence it passes obliquely outwards, forwards, and upwards, and enters the meatus auditorius internus, the foramen of which is situated on the posterior surface of the pars petrosa. The base of this meatus corresponds to the inner surface of the vestibule, and to the base of the cochlea. Through the first foramen, near the base of the meatus, the portio dura of the seventh pair or facial nerve passes, to gain the aqueduct of Fallopius, along which it proceeds, giving off filaments to different parts of the middle ear, and ultimately issuing by the stylo-mastoid foramen, to be lost on the muscles of the face.

Below the part of the meatus, where the facial nerve emerges, are several other foramina, through which the filaments of the auditory nerve attain the labyrinth. These are distributed to the vestibule, semicircular canals, and cochlea; and terminate, by very delicate ramifications, in the tissue and at the surface of the membrane, that lines the labyrinth.

Such are the organs concerned in the function of audition. Before proceeding to the physiology of these different parts, and the assistance afforded to the mind by this sense, it is necessary to enter into a brief physical disquisition on the subject of sound.

Of Sound.

If a body, by percussion or otherwise, be thrown into vibration, every vibration will excite a corresponding wave in the air; and these oscillations will be propagated, in all directions, until they are gradually lost in distance; but if they strike on the organ of hearing with the necessary force, a sensation is produced, which is called *sound* or *noise*. The term, however, is frequently used to signify, not only the sensation, but likewise the affection of the air, or of the sonorous body, by which the sensation is effected.

That bodies move or oscillate, when they produce sound, admits of easy detection. We can see it in drums, bells, musical strings, &c., whose vibrations, being extensive, are more perceptible; and we can arrest them, and with them the sound, by putting the hand upon the body, or by muffling it.

Whenever a sonorous body is struck, a change in the relative position of its molecules is produced. These, by virtue of their elasticity, tend to return to their former condition. This is done by a series of oscillations, which are, at first, more extensive, but become gradually less, until they finally cease. The rapidity of these oscillations is greater in bodies that are hard and elastic; and hence it has been concluded, that these two qualities render a body sonorous. It is not, however, a matter of facility to say, what is the precise cause of the difference of sound in analogous bodies. It must, of course, be dependent upon intimate composition, but of a character not easily intelligible to us. There is but one individual in Great Britain, who has been celebrated for the fabrication of the larger order of bells—for churches, colleges, &c.—and in certain countries the art is comparatively unknown. The resonance is entirely owing to the intimate composition of the body, and is beautifully and singularly exhibited in the *Chinese gong*, the sound of which will continue to rise for some time after a succession of rapid and forcible blows has been inflicted.

But, in order that the oscillations of a sonorous body may affect the organ of sense, an intermediate body is necessary to repeat and transmit them. This body is called the *vehicle of sound*, and it is usually the air.* The air is, by virtue of its elasticity, admirably

* Lamarck supposes the existence in the atmosphere of a vibrative fluid, of great subtilty, which penetrates the globe invisibly as well as the bodies on its surface: and Geoffroy St. Hilaire affirms, that sound "is a matter resulting from the combination of the external air with the polarized air of the sonorous body!"—but these are topics that belong to works on higher physics.

adapted for this purpose. The loudness of the sound, conveyed by the air, is dependent upon the density of that medium. If we put a bell under the receiver of an air pump, and exhaust the air, the sound will become gradually more and more faint, and when the air is exhausted will not be heard at all. For the same reason a pistol fired on the top of the Himālā mountains gives a much feebler report than in the valleys beneath. *Sympathetic sounds* afford additional evidences of the carrying power of air. Every sonorous, elastic body can be thrown into oscillations, provided the air around it be made to tremble in any manner. Thus, if we sound a note near a piano-forte, whose dampers are raised so as to admit of free vibration, the string, that is in unison with the tone produced, will vibrate; and a wine-glass or goblet may, according to Arnott, be made to tremble, and even to fall from a table, by sounding on a violoncello near it, the note that accords with its own.

The strata of air, in proximity with the sonorous body, receive the first impulses; and from these they are successively propagated to others; much in the same manner as the undulations extend from the place in which a stone is cast on a surface of smooth water; except, that the aerial undulations usually extend in every direction, whilst the aqueous proceed only horizontally. In this propagation from stratum to stratum a portion of the sound is necessarily lost; so that the loudest sounds are heard only within certain limits; and, in all cases, the intensity of the sound is inversely as the square of the distance from the sonorous body.

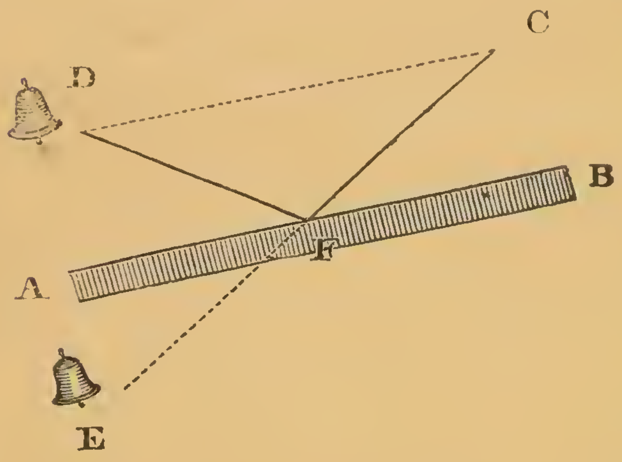
By causing the sonorous undulations to proceed entirely in one direction, and preventing their escape in every other, a sound may be rendered audible at a much greater distance. Biot found, that when he spoke in a whisper at one extremity of a cylinder upwards of one thousand yards long, he was distinctly heard at the other. In many large manufactories the knowledge of this fact is turned to good account. By having numerous tubes communicating with the different rooms of the establishment, and terminating in the office of the principal, he is enabled to have his directions readily conveyed, and to receive any information he may require, without the slightest inconvenience.

The velocity, with which sound proceeds, admits of easy calculation. Light passes with such rapidity, that it may be regarded as proceeding from objects on the earth instantaneously to the eye. The velocity of sound is incomparably less. We see the flash of a gun at a distance; and, some time afterwards, we hear the report. Considering the light then to have reached the eye instantaneously, if we know the distance of the gun, and note the time that elapsed between the appearance of the flash and the report, we can calculate accurately the rapidity of sound. This is found to be about eleven hundred and forty-two feet in a second. We can, in this manner, tell the distance of a thunder cloud, by noting the time of the flash, and the time that elapses before hearing the clap. If it be thirty seconds, the cloud is at the distance of thirty times eleven hundred and forty-two feet, or of six miles and a half.

This velocity is the same for all kinds of sounds. Biot found, on playing a flute at the end of the tube, above referred to, that the tones arrived at the ear placed at the other extremity in due succession; so that their velocity must have been uniform.

When the aerial oscillations meet with a resisting body of a regular surface, as A B, Fig. 18, they are reflected at an angle equal to the angle of incidence: consequently an ear, placed in the course of these reflected waves as at C, will refer the sound to a distance as far behind the point of reflection, and in the direction of the reflected ray, as the sonorous body is from the point of reflection. It will seem to be at E. The ear at C will, however, receive the direct oscillations from the bell D, as well as those that proceed along the lines D F and F C; or, in other words, it will hear both the sound and its *echo;* and, if the surfaces on which the sonorous undulations impinge be favourably disposed, these echoes may be very numerous.

Fig. 21.



The utility of the *ear trumpet*, and of the *speaking trumpet* is to be explained by this law of the reflection of the aerial undulations: and some physiologists are of opinion, that the external ear is inservient to audition on similar principles. The *ear trumpet* is a tube, narrow at one extremity, so as to enter the concha; and expanded at the other like a trumpet. It is also curved, so that it may be easily directed to objects. All the sonorous rays, which enter the expanded extremity, after various reflections, are brought to a focus in the auricular end; and the intensity of the sound is, in this way, so much augmented, that a person, who, without it, is entirely deaf to common conversation, may be able to enjoy it. A sheet of paper, folded like a cone, the apex of which is placed in the concha, serves a like purpose; and, to a less extent, the hand held concavely behind the ear.

Air is not the only, or the most perfect, vehicle of sound. The personal experiments of divers show, that it can be conveyed through water. The blows of workmen around a diving bell are distinctly heard above; and fishes have manifestly an acute sense of hearing, although this was at one time denied. An experiment, made by Franklin, and by the Abbé Nollet, proves, that water transmits a much stronger vibration than air. When they struck two stones together under water, a shock was given to the ear, which was almost insupportable. The former philosopher found by experiment, that sound, after travelling above a mile through water, loses but little of its intensity. According to Chladni, the velocity of sound in water is about 4900 feet in a second, or between four and five times as great as in air.

Solids, too, are much better conductors of sound than air. If we scratch one end of a wooden rod, the sound will be distinctly heard by the ear applied to the other, although it may be inaudible through the air. Savage tribes are in the habit of discovering the advance of enemies, or of their prey, by applying the ear to the ground; and the watchmen, in some of the towns, instead of springing a rattle, and alarming offenders, strike the pavement with a staff, the sound of which is heard by their fellow watchmen at a considerable distance. It is a common practice to ascertain whether a kettle boils, by putting one end of a poker on the lid, and the other to the ear. The difference between simmering and boiling is in this way easily detected. A knowledge of this fact, and of the ready communication of sound through solids, has lately given rise to a valuable suggestion for the discrimination of the diseases of the chest, and of various physiological and pathological conditions. By putting the ear to the chest we can hear the rush of the air along the bronchial tubes: the pulsations of the heart, &c. and can discover any aberration, that takes place in the execution of their functions. This is what has been called, by the late distinguished Laennec, of Paris—the proposer of the method—*immediate auscultation*. The direct application of the ear to the chest is, however, frequently inadmissible. In these cases Laennec used a hollow cylinder, called a *stethoscope*, one end of which he applied to the chest—the other to the ear. This plan he termed *mediate auscultation*. The suggestion has led to most valuable improvements in diagnosis.

Hassenfratz and Biot have made some accurate experiments on the comparative rapidity of the progress of sound through air and solid bodies. The latter found, in the aqueducts of Paris, that a blow, struck upon a pipe nine hundred and fifty-one metres, or about ten hundred and forty yards in length, was heard two seconds and a half sooner through the sides of the pipe than through the air; but the sound did not extend so far. Ice conveys sound even better than water; for if cannon be fired from a distant post—a frozen river intervening—each flash is followed by two distinct reports, the first conveyed by the ice,—the second by the air.

It has been already observed, that the vibrations of the air, caused by a sonorous body, are capable of exciting corresponding or *sympathetic vibrations* in solid bodies within their sphere of action. It was an old observation, that such vibrations are excited only in bodies in unison with the sonorous body; in other words, in those that are capable of producing the same tone with the latter. M. Savart has, however, found, that unison is not necessary; and that when a sound is produced in the air, every body receives a vibration, which is a repetition of the one that occasions the sound. This he proved by using small membranes, on which he placed fine sand. These were agitated, and the sand assumed various regular arrangements, whenever a sound was produced in their vicinity. This law of physics is important in its physiological relations. The apparatus of audition consists of several membranous structures, which are thrown into oscillations, whenever the ear receives the impressions of sound.

The vibrations, which produce sound, differ much as regards their extent and rapidity; and on these differences are dependent two of the qualities of sound—*strength* and *tone*.

The *strength* or *intensity* of sound depends on the extent of the vibrations of a sonorous body. This is easily seen in a musical string; the sound of which becomes weaker as the extent of the oscillations diminishes.

The *tone*, on the other hand, is dependent on the rapidity of the oscillations;—on their number in a given time. The tone, produced by a string or other sonorous body that vibrates quickly, is termed *acute* or *sharp*, when compared with the tone of one that vibrates more slowly. The latter is called *grave*, when compared with the former.

The gravest sound, that the ear can appreciate, is ordinarily considered to result from thirty-two vibrations per second; the most acute, from eight thousand one hundred and ninety-two vibrations, according to some;—twelve thousand, according to others. Some well devised experiments, recently made by Savart, largely extend these limits, and appear to indicate, that they cannot yet be rigidly fixed. In his experiments, the ear distinctly appreciated fourteen or sixteen vibrations per second; and the acutest note, that was audible, proceeded from upwards of forty thousand simple oscillations, per second.

The duration of the impression of a sonorous vibration on the ear is about the sixteenth part of a second.

If a sonorous body be struck, and the vibrations excited be all performed in equal times, a simple and uniform sensation will be produced on the auditory nerve, and one *musical tone* will be heard. But if the vibrations be various and irregular, they will fall irregularly on the organ of hearing, and will excite a harsh impression, as if various sounds were heard together. In other words, a *noise* or *discord* will be produced.

If two notes, sounded together, afford pleasure, they produce *harmony* or *concord*. This arises from the agreement of the vibrations of the two sonorous bodies, so that some of the vibrations of each strike upon the ear at the same time. If, for example, the vibrations of one sonorous body take place in double the time of another, the second vibration of the latter will strike upon the ear at the same instant as the first vibration of the former. This is the concord or harmony of an *octave*. Between a note and its octave, there are six intermediate notes, constituting the *diatonic scale* or *gamut*. If the vibrations of two strings are as two to three, the second vibration of the former will correspond with the third vibration of the latter, producing the harmony called *a fifth*. There are other tones, which, although they cannot be struck together without producing discord, if struck in succession, may give the pleasure called *melody*. *Melody* is, in truth, nothing more than the effect produced on the brain by pleasing musical tones, sounded in succession.

There is another quality of sound, which the French call *timbre*. By some of the translators of the works of the French physiologists, this word has been inaccurately rendered *note*. It is essentially different from note or tone, and is peculiar. By English philosophers it is termed the *quality* of sound. It is this *quality* that enables us to recognize various instruments, although sounding the same note or tone; and to distinguish the voices of individuals from each other. Its cause is not evident. By most, it is conceived to depend upon the nature of a sonorous body, if it be a surface,—and at the same time on its shape, if a tube. Biot conjectures, that it is owing to the series of harmonic sounds forming part of every appreciable sound. When any sonorous body is made to vibrate, a distinct sound is heard, which is the *fundamental*; but, if attention be paid, others will be heard at the same time. These are called *harmonics*.

It is not improbable but that the *timbre* or *quality* may be dependent as well upon the nature of the sonorous body, as upon the greater or less number of harmonics, that accompany the fundamental sound.

Physiology of Audition.

In tracing the progress of the sonorous vibrations to the internal ear, we shall follow the order of parts described in the anatomical sketch of the auditory apparatus;—commencing with the *external ear*.

The meatus auditorius externus being always open, sonorous vibrations can readily attain the membrana tympani. Some of these pass directly to the membrane without experiencing reflection, and communicate their oscillations to it. The *pavilion*, by most physiologists, has been regarded as a kind of ear trumpet, for collecting the aerial undulations, and directing them, after various reflections, to the bottom of the auditory canal. In the horse, and in those animals, which have the power of pricking the ears, or of moving them in various directions, this is doubtless the case; but in man we cannot expect any great effect of the kind, if we regard its particular arrangement, and the incapability of moving it from its fixed direction, which is nearly parallel to the head. Boerhaave, indeed, pretended to have proved by calculation, that every sonorous ray, which falls upon the pavilion, is ultimately directed towards the meatus auditorius externus. Simple inspection of the pavilion will show that this cannot be universally true. Some part of the anthelix is, in almost every individual, more prominent than the helix; and it is therefore impossible for the undulations, that fall upon its posterior surface, to be reflected towards the concha.

M. Itard, a distinguished physiologist and aurist of Paris, asserts, that he has never seen the loss of the pavilion affect the hearing; and that, as is well known, many animals, whose sense of hearing is extremely acute,—the mole and birds, for example,—are devoid of it. Hence he concludes, that it is perhaps rather injurious than favourable to audition, and is more inservient to the expression than to the hearing of the animal. M. Itard's view is doubtless too exclusive. The pavilion may have but little agency as an ear trumpet, but it must have some. The concha, being the expanded extremity of the meatus auditorius, must receive more sonorous vibrations than could be admitted by the meatus itself. These are reflected towards the membrani tympani, and reach that expansion in a state of concentration—but to no great extent, it is true. In this way, and perhaps in that suggested by M. Savart, the pavilion is useful in audition. That gentleman is of opinion, that the whole of the external ear, the elasticity of which he considers to be capable of slight modification by the action of its proper muscles, is an apparatus for *repeating* sonorous vibrations, and transmitting them along its own parietes to the membrane of the tympanum. According to this view, the different inequalities of surface in the pavilion admit of explanation. When a membrane is stretched in a direction parallel to a sonorous surface, the oscillations, impressed upon it, are most marked; and, accordingly, as sounds impinge upon the pavilion from various quarters, the inequalities of surface, always admit of some being disposed in the most favourable way for the reception of the vibrations. It is true, however, that the pavilion is not essential to audition; the hearing not suffering by its removal for more than a few days; so that its physiological influence is much more limited than might be conceived.

The *meatus auditorius externus* conducts the sonorous vibrations directly, and by reflection, to the membrana tympani, as well as by its parietes. It is probable, too, that it is useful in protecting the membrane from the direct action of the air and extraneous bodies. This is perhaps the cause of its tortuous character in all animals. If too tortuous, the sense of hearing becomes impaired,—the sonorous oscillations not being properly directed towards the membrane. Baron Larrey has published some cases of deafness produced in this manner, which were removed by wearing an artificial concha and meatus, of the natural curvature, made of gum elastic. The down or hairs, at the entrance of the meatus, have also been regarded as protecting agents against the intrusion of extraneous bodies; whilst the cerumen has been looked upon as a fit material for entrapping insects in the slough formed by it, or for destroying them by its poisonous influence. It is probable, however, that the most important function of the cerumen is to keep the lining membrane of the meatus in a physical condition, adapted for the proper fulfilment of its functions.

Middle Ear.—In the mode described, the vibrations of a sonorous body attain the membrana tympani. An experiment by Savart would seem to show, that this membrane is thrown into vibrations chiefly by the air contained in the meatus. He made a small truncated cone of pasteboard, and closed the smaller extremity by a tense membrane, nearly as the membrana tympani closes the inner extremity of the meatus auditorius; and he found, that when sounds were produced near the parietes of the cone, the membrane vibrated but little; whilst, if they were occasioned opposite the base of the cone, so that they could be transmitted to the membrane by the air within the canal, the vibrations were very distinct, even at a distance of thirty yards and upwards.

The membrane of the tympanum, then, receives and repeats the sonorous vibrations. It has, however, been supposed to be possessed of other functions. Dumas, for example, conceived it to be composed of numerous cords, and each of these to correspond to some particular tone. But of this arrangement we have not the slightest evidence from observation or analogy.

By others, it has been supposed, and with every probability, that the membrane is capable of being rendered tense, or the contrary, by the bent lever, formed by the chain of small bones. They have farther stated, that this tension or relaxation is adapted to the sounds, which the membrane has to transmit.

The ancients believed, that the adaptation was produced by the stretching of the membrane, so as to put it in unison with the sound produced. Independently, however, of the experiments of Savart, which show, that unison is not necessary for the production of vibrations, the fact, that we are capable of distinguishing several sounds at the same time, would be sufficient to negative the supposition. Nor can we easily conceive, that the membrane could admit of as many distinct vibrations as the ear is capable of accurately appreciating tones, which amount to about eight octaves.

Bichat thought, that the degree of tension of the membrane corresponded with the intensity of sounds; and that its effect was to cause the sonorous vibration to attain the internal ear, in a degree sufficiently strong to excite the appropriate impression, but not so strong as to cause pain,—the membrane becoming more tense for a feeble sound, and relaxed for one too strong. In support of this view, Bichat cites the case of several persons, who could not hear ordinary sounds, until the ear had been impressed by louder, which, according to him, roused the membrane to tension.

Savart, on the other hand, from the fact, that every membrane vibrates with more difficulty, and less extensively, according to its tension, conjectures, that the membrane is relaxed in the case of very feeble or agreeable sounds, and that it is rendered tense to transmit the too powerful or the disagreeable.

Again, it has been conceived, that the tension varies with the tone of the sound,—being augmented according to some physiolo gists in the case of acute, according to others, in that of grave, sounds.

Sir Everard Home, it has been remarked, esteems the membrana tympani to be muscular: and he affirms, that it is chiefly by means of this muscle, that accurate perceptions of sound are made by the internal organ; and that by it the membrane can alter its degree of tension. It has been already observed, that the muscles, attached to the small bones, are capable of varying this tension; that the internal muscle of the malleus or tensor tympani, for example, by its contraction, renders it more tense. Sir Everard admits, "that the membrana tympani is relaxed by the muscles of the malleus, but not for the purpose alleged in the commonly received theory. It is stretched in order to bring the radiated muscle of the membrane itself into a state capable of acting, and of giving those different degrees of tension to the membrane, which empower it to correspond with the variety of external tremors; when the membrane is relaxed, the radiated muscle cannot act with any effect, and external tremors make less accurate impressions."

The reader is referred to the remarks already made on the views of Sir Everard in their anatomical relations. His speculations do not, however, end here. He employs the discovery to account for the difference between a musical ear, as it is usually termed, and one which is incapable of discriminating, or feeling pleasure from, the succession of musical tones,—with what success we shall inquire presently.

The truth is, that none of the conjectures, which have been proposed, regarding the precise effects of tension or relaxation of this membrane, can be looked upon in any other light than as ingenious speculations, based, generally, upon the fact, that the membrane seems certainly capable of being varied in its tension by the movements of the chain of bones, but leading us to no certain knowledge of the precise effect on audition of such tension or relaxation.

In fact, although the integrity of the membrana tympani is necessary for perfect hearing, its perforation or destruction does not induce deafness. We have numerous cases of perforation from accident and otherwise, related by Valsalva, Willis, Riolan, Flourens, and others, in which the hearing continued; and, in certain cases of deafness, the membrane is actually punctured for the purpose of restoring the hearing.

The communication of sonorous oscillations from the membrana tympani, across the cavity of the tympanum to the internal ear, is effected in three different ways; 1, by the air contained in the cavity of the tympanum; 2dly, by the chain of bones to the membrane of the foramen ovale; and 3dly, by the parietes of the tympanum. So that, if the membrana tympani should be punctured or destroyed, the aerial undulations, caused by a sonorous body, and which enter the meatus auditorius, may extend into the cavity of the tympanum, and excite corresponding oscillations in the membranes of the foramen ovale, and foramen rotundum.

The chorda tympani composed, as we have seen, of a branch of the fifth pair and of the portio dura of the seventh, and distributed on the interior surface of the membrana tympani—probably conveys no acoustic impression to the brain. To it is owing the excessive pain, caused by the contact of an extraneous body with the membrane, and that occasioned by a loud noise, or by compressing the air forcibly in the meatus by passing the finger suddenly and strongly into the concha.

The uses of the *mastoid cells*, which communicate with the middle ear, are not known. It would seem, that the strength of audition is in a ratio with their extent. In no animals are they more ample than in birds, which are possessed of great delicacy of hearing. This effect may be induced either by their enlarging the cavity of the tympanum, and allowing the sonorous oscillations to come in contact with a larger surface; or by the plates, which compose them, being thrown into vibration. It has been conceived, too, that they may serve as a diverticulum for the air in the middle ear, when subjected by the membrana tympani to unusual compression.

Sir Charles Bell, with more warmth than is judicious or courteous, combats the idea of the *foramen rotundum* receiving the undulations of air. The oblique position of the membrane of the foramen, with regard to the membrana tympani, satisfactorily, he thinks, opposes this doctrine. The function, which, with Savart, he assigns to it—if not accurately, at least ingeniously—is the following. As the membrane of the foramen ovale receives the vibrations from the chain of small bones, these vibrations circulate through the intricate windings of the labyrinth and are again transmitted to the air in the tympanum by the foramen rotundum. The different cavities of the labyrinth, being filled with an incompressible fluid, no such circulation, he insists, would occur, provided the parts were entirely osseous. As it is, the membrane of the foramen rotundum gives way, "and this leads the course of the undulations of the fluid in the labyrinth in a certain unchangeable direction."

The explanation of Sir C. Bell is not as convincing to us as it seems to be to himself. The membrane of the foramen rotundum does not appear to be required for the undulation in the cavities of the labyrinth, which he describes, as the liquor of Cotunnius can readily reflow into the aqueducts of the vestibule and cochlea. The principal use of these canals would seem, indeed, to be, to form *diverticula* for the liquor, when it receives the aerial impulses.

Sir C. Bell cites the case, often quoted from Riolan, of an individual, who was deaf from birth, and who was restored to hearing by accidentally rupturing the membrana tympani, and breaking the ossicles with an ear-pick—"*disrupit tympanum, fregitque ossicula, et audivit.*" In these and other cases, in which the membrana tympani and ossicles have been destroyed, and the hearing has still persisted, the vibrations must have been conveyed to the parietes of the internal ear through the air in the cavity of the tympanum, and, notwithstanding the charge of "absolute confusion of ideas," adduced against such individuals as Scarpa, Magendie, Adelon, and others, who believe that the foramen rotundum receives the undulations of the air, we must confess, that the idea of the communication of vibrations through that medium, as well as through the membrane of the foramen ovale, and the osseous parietes of the labyrinth, appears to us most solid and satisfactory.

The *ossicles* or *small bones* have given occasion to the wildest speculations. At the present day, they are considered to fulfil one of two functions;—either to conduct the vibrations from the membrana tympani, or to stretch the membranes to which the extremities of the chain are attached. Both these offices are probably executed by them, the malleus receiving the vibrations from the membrana tympani, and conveying them to the incus,—the incus to the os orbiculare,—the os orbiculare to the stapes, and the stapes to the membrane of the foramen ovale by which they are transmitted to the liquor of Cotunnius. Savart conceives, that the chain of ossicles is to the ear what the bridge is to the violin. It has been already observed, that the ossicles are not essential to hearing, although they may be required to perfect it; and that they may be destroyed, without deafness being produced, provided the membrane of the foramen ovale remains entire, and the parts within the labyrinth retain their integrity. If, in the removal of the stapes by ulceration or otherwise, the membrane of the foramen were to be ruptured, the liquor of Cotunnius would of course escape, and partial or total deafness be the result. In some experiments, instituted by Flourens on pigeons, he found, that the removal of the malleus and incus did not have much effect upon the hearing; but when the stapes was taken away it was greatly diminished, and still more so when the membranes of the fenestra ovalis and fenestra rotunda were destroyed.

The *Eustachian tube* is an important part of the auditory apparatus, and an invariable accompaniment of the membrana tympani, in animals. Without the tube, the membrane would be devoid of function. Pathology shows us, in the clearest manner, that its integrity is necessary to audition; and that deafness is the consequence of its closure. Dr. Bostock thinks, "it is perhaps not very easy to ascertain in what mode it acts, but it may be concluded that the proper vibration of the membrana tympani is, in some way, connected with the state of the air in the tube." The name of the cavity to which the tube forms a communication with the external air might have suggested an easy and sufficient explanation of its use. The *drum* of the ear, like every other drum, requires an aperture in some part of its parietes, in order that its membranes may vibrate. The Eustachian tube serves this purpose, and its closure produces the same effect upon the membrana tympani at one end of the cylinder, and on the membrane of the foramen ovale at the other, as would be produced on the parchments of the ordinary drum by the closure of its lateral aperture. We can, in this way, account for the temporary deafness, which accompanies severe cases of inflammation of the throat: the swelling obstructs the Eustachian tube.

During the constant efforts of deglutition the air is renewed in the cavity of the tympanum; and, as the extremities of the Eustachian tube terminate in the pharynx, it always enters at a subdued temperature.

By closing the nose and mouth, and forcing air from the lungs, we can feel a sensation of fulness in the ear, produced by the pressure of the air against the internal surface of the membrana tympani; and they, who have the membrane perforated, can send tobacco smoke copiously out of the external ear.

Besides this necessary function, the Eustachian tube has been supposed to possess another,—that of serving as a second meatus auditorius, by permitting sonorous vibrations to enter through the pharyngeal extremity, and, in this way, to attain the internal ear. A simple experiment, first described by Perolle, exhibits the fallacy of this notion. If we carry a watch far back into the mouth, taking care not to touch the teeth, little or no sound will be heard, but if we draw the watch forward, so as to touch the teeth, the ticking becomes distinctly audible. If the pharyngeal extremity acted as a second meatus, the sound ought to be heard better when the watch is placed nearer to it; but this is not the case. On the contrary, it is not until the sonorous body is put in contact with the teeth, that the sound is appreciated. This is effected by the vibrations of the watch being conveyed along the bony parietes until they reach the auditory nerve.

Again, if the meatus auditorius externus be completely closed, we cannot hear the voice of one who speaks into the mouth; and can hear but imperfectly our own. The fact of our gaping, when desirous of hearing accurately, has partly led to the belief, that the Eustachian tube acts as a second meatus. It has been properly remarked, however, that this may be merely an act of expression; and, also, that the meatus auditorius is rendered more open, when we depress the lower jaw, than when it is raised, as can be readily perceived by inserting the little finger into the meatus, when the jaw is in either situation.

In addition to these functions, it is probable, that the Eustachian tube acts as a diverticulum for the air in the cavity of the tympanum, when it is agitated by too powerful sounds.

Internal Ear.—In the various ways mentioned, the vibrations of a sonorous body reach the internal ear. The membranes of the foramen ovale and foramen rotundum resemble the membrana tympani in their physical characteristics; and, when thrown into vibration, communicate the impression to the liquor of Cotunnius, which fills the cavities of the internal ear. By this medium the vibrations are conducted to the auditory nerve, which conveys the impression to the brain.

The views, entertained regarding the sympathetic vibrations of the membrana tympani, have almost all been applied to the membrane of the foramen ovale: our knowledge, however, is restricted to the fact, that its tension can be varied by the chain of bones, without our being able to specify the circumstances under which this takes place. Adelon asserts, that the membrane may be torn, and yet the sense of hearing not be destroyed. This seems scarcely possible, as the liquor of Cotunnius must necessarily escape, and so much morbid action be induced as to render audition apparently impracticable.

The membrane of the foramen rotundum, which forms the medium of communication between the cavity of the tympanum and the cochlea, has, of course, no chain of bones to modify its tension. Both the vibrations into which it is thrown, and those of the vestibular membrane, are imparted, as we have seen, to the *liquor of Cotunnius*, which fills all the different cavities of the labyrinth, is present in every ear, and appears essential to audition.

Of the precise uses of the *vestibule*, *semicircular canals*, and *cochlea*, we have very limited notions. The beauty and complexity of their arrangement, has, however, given rise to various conjectures. Lecat considered the lamina spiralis to consist of numerous minute cords, stretched along it, and capable of responding to every tone. Magendie affirms, that no one at the present day admits the hypothesis regarding the use of this osseo-membranous septum; but he is in error. Sir C. Bell asserts, that the cochlea is the most important part of the organ of hearing; or rather, that it is "the refined and higher part of the apparatus;" and he considers the lamina spiralis as the only part adapted to the curious and admirable powers of the human ear, for the enjoyment of melody and harmony.

The subject of the musical ear will engage us presently. It may be sufficient to remark, in this place, that there is no ratio, in animals, between the delicacy of the hearing, and the degree of complication of the cochlea. The cochlea of the Guinea pig is more convoluted than that of man, yet we can hardly conceive it to have a better appreciation of musical tones; whilst in birds, whose hearing is unquestionably delicate, the organ is, as we have remarked, extremely simple, and has no spiral arrangement.

Again, the semicular canals have been compared to organ pipes, adapted for producing numerous tones; and Dr. Young supposed them to be "very capable of assisting in the estimation of the acuteness or pitch of a sound, by receiving its impression at their opposite ends; and occasioning a recurrence of similar effects at different points of their length, according to the different character of the sound; while the greater or less pressure of the stapes must serve to moderate the tension of the fluid within the vestibule, which serves to convey the impression." "The cochlea," he adds, "seems to be pretty evidently a micrometer of sound." All these are mere hypotheses;—ingenious, it is true, but still hypotheses: and, in candour, we must admit, that we have no positive knowledge of the precise functions of either vestibule, cochlea, or semicircular canals. Our acquaintance with them is limited to this; that they contain the final expansions of the auditory nerve; and that it is within them, that this nerve receives its impressions from the oscillations of sonorous bodies.

It has been observed, that these vibrations may reach the nerve by the bony parietes, and that the ticking of a watch, held between the teeth, is, in this way, heard. A blow upon the head is distinctly audible; and Ingrassias relates the case of a person, who had become deaf in consequence of obstruction of the meatus auditorius externus, and yet could hear the sound of a guitar, by placing the handle between his teeth, or by making a communication between his teeth and the instrument by a metallic or other rod. The physician has recourse to a plan of this kind for detecting whether a case of deafness be dependent upon obstructed Eustachian tube—upon some affection of the meatus auditorius externus—or upon insensibility of the auditory nerve, or of the part of the brain that effects the sensation. If the latter be the case, the ticking of a watch, applied to the teeth, will not be audible, and the case may necessarily be one of a hopeless character. If, on the other hand, the sound be perceived, the attention of the physician may be directed, with well founded expectations of success, to the physical parts of the organ, or to those concerned in the transmission of vibrations. Frequently, it will happen, in such cases, that the Eustachian tube is impervious, and properly directed efforts may succeed in removing the obstruction; or, if this be impracticable, temporary, if not permanent, relief may be obtained by puncturing the membrana tympani, and allowing the aerial undulations, in this way, to reach the middle and internal ear.

Professor Mojon, of Geneva, is of opinion, that the cranium serves as an harmonic case, or drum, which communicates its vibrations to the auditory organs. Numerous observations have induced him to infer, that the cranium is by no means passive in the perception of sounds, and that differences in the thickness of its walls may have considerable influence in determining the degree of acuteness of the faculty.

Lastly—as regards the precise nerve of hearing. In this sense we have the distinction between the nerve of general, and that of special sensibility, more clearly observed. The experiments of Magendie have shown, that the portio mollis of the seventh pair is the nerve of special sensibility;—that it may be cut, pricked, or torn, without exhibiting any general sensibility, and that it is inservient only to the sense of hearing. The same experiments demonstrate, that this nerve cannot act, unless the fifth pair or nerve of general sensibility be in a state of integrity. If the latter nerve be divided within the cranium, the hearing is always enfeebled, and frequently destroyed. The experiments of Flourens, to which allusion has been made, led him to infer, that the rupture of the cochlea was of less consequence than that of the semicircular canals. Laceration of the nerve, distributed to the vestibule, enfeebled the hearing, and its total destruction was followed by irreparable deafness. For these, and other reasons, furnished by comparative anatomy, Lepelletier infers, that, in the higher organisms, the vestibule and its nerve constitute the essential organ of impression, the other parts being superadded to perfect the apparatus.

The immediate function of the sense of hearing is to appreciate sound; and we may apply to it what has been said of the other senses, that, in this respect, it cannot be supplied by any other sense —that it is instinctive, requires no education, and is exerted as soon as the parts have attained the necessary degree of developement.

Amongst the advantages afforded by the possession of this sense, which has been properly termed *intellectual*, are two of the highest gratifications we enjoy—the appreciation of music, and the pleasures of conversation. It is to it that we are indirectly indebted for the use of verbal language—the happiest of all inventions —as it has been properly termed, and to which we shall have to advert in the course of our inquiry into the animal functions.

Metaphysicians and physiologists have differed considerably in their views regarding the organs more immediately concerned in the appreciations in question. Many, for example, have referred the faculty of music to the ear; and hence, in common language, we speak of an individual, who has a "*musical ear*," or the contrary. Others, more philosophically we think, have considered, that the faculty is seated in the encephalon; that the ear is merely the instrument for conveying the sonorous undulations, which, in due order, constitute melody, but that the appreciation is ultimately effected in the brain. "That it," (the power of distinguishing the musical relations of sounds,) says Dr. Brown, "depends chiefly or perhaps entirely, on the structure or state of the mere corporeal organ of hearing, which is of a kind, it must be remembered, peculiarly complicated, and therefore susceptible of great original diversity in the parts, and relations of the parts that form it, is very probable; though the difference of the separate parts themselves, or of their relations to each other may, to the mere eye, be so minute, as never to be discovered by dissection." Many physiologists of eminence have regarded the complex internal ear as the seat of the faculty; some looking to the cochlea; others to the semicircular canals, but few referring it to the brain. Sir C. Bell, indeed, asserts, that "we are not perhaps warranted in concluding, that any one part of the organ of hearing bestows the pleasures of melody and harmony, since the musical ear, though so termed, is rather a faculty depending on the mind." Yet afterwards he adds—"we think that we find in the lamina spiralis (of the cochlea) the only part adapted to the curious and admirable powers of the human ear, for the enjoyment of melody and harmony. It is in vain to say, that these capacities are in the mind and not in the outward organ. It is true, the capacity for enjoyment or genius for music is in the mind. All we contend for is, that those curious varieties of sound, which constitute the source of this enjoyment, are communicated through the ear, and that the ear has *mechanical* provisions for every change of sensation."

A cherished opinion of Sir Everard Home on this subject has been referred to. Conceiving the membrane of the tympanum to be muscular, he considers the membrana tympani, with its tensor and radiated muscles, to resemble a monochord, "of which the membrana tympani is the string; the tensor muscle the screw, giving the necessary tension to make the string perform its proper scale of vibrations; and the radiated muscle acting upon the membrane, like the movable bridge of the monochord, adjusting it to the vibrations required to be produced;" and he adds, "the difference between a musical ear and one which is too imperfect to distinguish the different notes in music, will appear to arise entirely from the greater or less nicety with which the muscle of the malleus renders the membrane capable of being truly adjusted. If the tension be perfect, all the variations produced by the action of the radiated muscle will be equally correct, and the ear truly musical."

In this view,—as unsatisfactory in its basis as it is in some of the details,—Sir Everard completely excludes, from all participation in the function, the internal ear, to which the attention of physiologists, who consider the faculty to be seated in the ear, has been almost exclusively directed.

A single case, detailed by Sir Astley Cooper, in the Transactions of the Royal Society, for 1800 and 1801, prostrates the whole of the ingenious fabric, erected by Sir Everard. Allusion has already been made to the old established fact, that the membrane of the tympanum may be destroyed without loss of hearing necessarily following. Sir Astley was consulted by a gentleman, who had been attacked, at the age of ten years, with an inflammation and suppuration in his left ear, which continued discharging matter for several weeks. In the space of about twelve months after the first attack, symptoms of a similar kind took place in the right ear, from which matter issued for a considerable time. The discharge, in each instance, was thin, and extremely offensive; and in it, bones or pieces of bones were observable. In consequence of these attacks he became deaf, and remained so for three months. The hearing then began to return; and in about ten months from the last attack, he was restored to the state he was in when the case was published. Having filled his mouth with air, he closed his nostrils and contracted the cheeks; the air, thus compressed, was heard to rush through the meatus auditorius with a whistling noise, and the hair, hanging from the temples, became agitated by the current of air, that issued from the ear. When a candle was applied, the flame was agitated in a similar manner. Sir Astley passed a probe into each ear, and thought the membrane of the left side was totally destroyed, as the probe struck against the petrous portion of the temporal bone. The space, usually occupied by the membrana tympani, was found to be an aperture without one trace of membrane remaining. On the right side, also, a probe could be passed into the cavity of the tympanum; but, on this side, some remains of the circumference of the membrane could be discovered, with a circular opening in the centre, about a quarter of an inch in diameter. Yet this gentleman was not only capable of hearing every thing that was said in company, but was nicely susceptible to musical tones; "he played well on the flute, and had frequently borne a part in a concert; and he sung with much taste and perfectly in tune."

But, independently of these partial objections, the views, that assign musical ear and acquired language to the auditory apparatus, appear liable to others that are insuperable. The man who is totally devoid of musical ear, hears the sound distinctly. His sense of hearing may be as acute as that of the best musician. It is his appreciation that is defective. He hears the sound, but is incapable of communicating it to others. The organ of appreciation is—in this, as in every other sense—the brain. The physical part of the organ may modify the impression, which has to be made upon the nerve of sense, the latter is compelled to transmit the impression as it receives it; and it is not until the brain has acted, that perception takes place, or that any idea of the physical cause of the impression is excited in the mind. If, from faulty organization, such idea is not formed in the case of musical tones, the individual is said not to possess a musical ear: but the fault lies in his cerebral conformation. We do not observe the slightest relation between musical talent and delicacy of hearing. The best musicians have not necessarily the most delicate sense; and, for the reasons already assigned, it will be manifest, why the idiot, whose hearing may be acute, is incapable of singing, as well as of speaking. Again, we do not see the least ratio in animals between the power and character of their music, and the condition of their auditory sense. We are compelled then to admit, that the faculties of music and speech are dependent upon the organization of the brain; that they require the ear as a secondary instrument; but that their degree of perfection is by no means in proportion to the delicacy of the sense of hearing. In these opinions, Gall, Broussais, Adelon, and other distinguished physiologists, concur.

"Speech," says Broussais, "is heard and repeated by all men, who are not deprived of the auditory sense, because they are all endowed with cerebral organization, fit to procure for them distinct ideas on the subject. Music, when viewed as a mere noise, is also heard by every one; but it furnishes ideas, sufficiently clear to be reproduced and communicated by those individuals only, whose frames are organized in a manner adapted to this kind of sensation."

Yet, although we must regard the musical faculty to be intellectual, and consequently elevated in the scale, it is hardly necessary to say, that its deficiency is no evidence of that mental and moral degradation, which has been depicted by poets and others;—as in the well known anathema of Shakespeare:—

> "The man that hath no music in himself,
> Nor is not mov'd with concord of sweet sounds,
> Is fit for treasons, stratagems and spoils;
> The motions of his spirit are dull as night,
> And his affections dark as Erebus:
> Let no such man be trusted."

Or in that of Beattie—

> "Is there a heart that music cannot melt?
> Alas! how is that rugged heart forlorn;
> Is there, who ne'er those mystic transports felt
> Of solitude and melancholy born!
> He needs not woo the muse; he is her scorn.
> The sophist's rope of cobweb he shall twine;
> Mope o'er the schoolman's peevish page; or mourn,
> And delve for life in mammon's dirty mine;
> Sneak with the scoundrel fox, or grunt with glutton swine."

In the classification of the objects of human knowledge, music has been ranked with poetry; but we meet with striking evidences of their wide separation. Whilst the professed musician is frequently devoid of all poetical talent, many excellent poets have no musical ear. Neither does the power of discriminating musical tones indicate that the possessor is favoured with the finer sensibilities of the mind; nor the want of it prove their deficiency. It has been a common remark, that, amongst professed musicians, the intellectual manifestations have been singularly and generally feeble;—a result partly occasioned by their attention having been almost entirely engrossed from childhood by their favourite pursuit, but not perhaps to be wholly explained by this circumstance; and, whilst we find them often unmarked by any of the kindlier sympathies, we see those, that are "not moved with concord of sweet sounds," alike distinguished as philosophers and philanthropists.

The defect, in these cases, differs probably in an essential manner, from one to which attention has been drawn by the late Dr. Wollaston, in the *Philosophical Transactions*, for 1820. In that communication he describes many curious facts, regarding, what he terms, a peculiarity in certain ears, which seem to have no defect in the general capacity of receiving sound, or in the perception of musical tones, but are insensible to very acute sounds. This insensibility commences when the vibrations have attained a certain degree of rapidity, beyond which all sounds are inaudible to ears thus constituted. Thus, according to Wollaston, certain persons cannot hear the chirp of the grasshopper; others the cry of the bat; and he refers to one case in which the note of the sparrow was not audible. Dr. Wollaston himself, was incapable of hearing any sound higher than six octaves above the middle E in the piano forte.

The defect would, at first sight, appear to be referable to the physical part of the ear, rather than to the auditory nerve, or to the part of the brain concerned in the appreciation of sounds;—the vibrations, that are performed with great rapidity, not being responded to by the parts of the organ destined for this purpose; and, consequently, never reaching the auditory nerve. Researches, however, of Savart—one of the most dexterous and ingenious experimenters of the day—seem to show, that the defective appreciation of acute sounds, in such cases, is not owing to their *acuteness*, but to their *feebleness;* that, if the sound can be made sufficiently intense, the ear is capable of hearing a note of upwards of forty thousand simple oscillations in a second; and that the cases, referred to by Wollaston, are, consequently, owing to defective hearing, rather than to insensibility to very *acute* sounds.

Another acquired perception of the ear is that of forming a judgment of the *distance* of bodies. This we do by attending to the loudness of the sound; for we instinctively lay it down as a principle, that a loud sound proceeds from a body that is near us, and a feeble sound from one more remote. This is the cause of numerous acoustic errors, in spite of reason and experience. In the theatres, the deception is often well managed, when the object is to give the idea of bodies approaching. The sound—that of martial music, for example—is rendered faint and subdued; and, under such circumstances, appears to proceed from the remote distance; whilst, by adding gradually and skilfully to its intensity, we are irresistibly led to the belief, that the army is approaching; and the illusion is completed by the appearance of the military band on the stage, allowing its soul-inspiring strains to vibrate freely in the air. In like manner we are deceived by the ventriloquist. He is aware of the law, that guides us in our estimation of distance, and, by skilfully modifying the intensity of his voice, according as he wishes to make the sound appear to proceed from a near or distant object, he irresistibly leads us into an acoustic error.

It requires education or experience to enable us to appreciate distances accurately by this sense, as well as to judge of their *position.* In the case, detailed by Magendie,—in his *Journal de Physiologie* for 1825,—of a boy, who after having been entirely deaf until the age of nine, was restored to hearing by M. Deleau, by means of injections thrown into the cavity of the tympanum through the pharyngeal extremity of the Eustachian tube, one of the most remarkable points was, his difficulty in acquiring a knowledge of the position of sonorous bodies.

In forming our judgment on this subject we require the use of both ears. In all other cases an impression made upon one only would perhaps be sufficient. To judge of the direction of a sound we compare the intensity of the impression on each ear, and form our deductions accordingly; and experiment shows, that if we close one ear we are led into errors, which are speedily dissipated by employing both. Still we are often deceived even under these last circumstances, and are compelled to call in the aid of sight. The blind afford us striking examples of accuracy, in this respect, in their acquired perceptions by the ear. In the *Belisar* of Zeune, the case of a blind man is cited from Diderot; who, guided by the direction of the voice, struck his brother, in a quarrel, on the forehead, with a missile, which brought him to the ground.

If the sonorous vibrations before reaching the ear are deflected from their course we are liable to deception, mistaking the echo often for the direct or radiant sound.

The ideas of *magnitude*, acquired by the ear, are few, and to a trifling extent only. They occasionally enable the blind to judge of the size of apartments, and this they are sometimes able to do with much accuracy. It is well known, that if a sound be confined within a small space, it appears much louder than when the sonorous undulations can extend farther; hence the greater noise, caused *directly* by a pistol fired in a room than in the open air. The sound *indirectly* produced will necessarily be modified by the different reflections or echoes, that may be excited. By attending to these circumstances—to the loudness of the voice and to the intensity of the reverberations occasioned by the walls, and by calling into their aid the experience they have had under similar circumstances—in other words, by effecting a strictly intellectual process—the blind attain the knowledge in question.

The *velocity* of a body is indicated by the rapid succession of the vibrations, that impress the ear, as well as by the change in their intensity if the body be moving along a surface or through the air. A carriage, approaching us with great velocity, is detected by the ear, from the rapidity with which the wheels strike against intervening obstacles; and by the gradual augmentation in the intensity of the sound thus produced. When opposite to us the intensity is greatest; and a declension gradually takes place until the sound is ultimately lost in the distance.

Lastly, by audition we can form some judgment of the nature of bodies, from the difference in the sounds emitted. It has been already remarked, that the *timbre* or *quality of sound*, can be accurately appreciated. By this *quality* we can distinguish between the sound of wood or of metal; of hollow or solid bodies, &c.; but in all these cases we are compelled to call in aid our experience, without which we should be completely at a loss; and to execute a very rapid, but often a very complicated intellectual operation.

To conclude:—audition may be exercised *passively* as well as *actively*; hence the difference between simply *hearing*, and *listening*. We cannot appreciate, in man, the precise effects produced on the different portions of the ear by volition;—whether, for example, the advantage be limited to the better direction given to the ear, as regards the sonorous body, and to the avoiding of all distraction, by confining the attention entirely to the impressions made on this sense; or whether, by it, the pavilion may not be made somewhat more tense by the contraction of its intrinsic and extrinsic muscles;—the membrana tympani, and the membranes of the foramen ovale by the contraction of the muscles of the ossicles; or, in fine, the auditory nerve be rendered better adapted for the reception of the impression, and the brain for its appreciation. All these points are insusceptible of direct observation, and experiment, and are, therefore, enveloped in uncertainty. In some animals—as the horse—the outer ear becomes an acoustic instrument under the guidance of volition; and is capable of being turned in every direction in which a sonorous body may be placed.

Like the other senses, that of hearing is largely improved by education or cultivation. The savage, who is accustomed, in the stillness of the forest, to listen to the approach of his enemies or of his prey, has the sense so delicate as to hear sounds, that are inaudible to one brought up in the din of the busy world.

The blind, for reasons more than once assigned, afford examples of extreme delicacy of this as well as of their other remaining senses. They are necessarily compelled to cultivate it more; and, lastly, the musician, by education, attains the perception of the nicest shades of musical tones. The aptitude is laid in cerebral organization, and is developed by the education of the instrument—the ear—as well as of the encephalic or intellectual organ, without which, as we have seen, no such appreciation could be accomplished.

Sect. V.—OF THE SENSE OF SIGHT, OR VISION.

The immediate function of the sense of sight is to give us the notion of light and colours. Like the other senses, it is a modification of that of touch, whether we regard the special irritant—light—as an emanation from luminous bodies, or as the vibration of a subtile, ethereal fluid, pervading all space. Under the latter theory it would most strongly resemble the sense last considered.

The pleasures and advantages, derived by the mind through this inlet, are of so signal a kind as to render the organ of vision a subject of universal interest. Every one, who lays the slightest claims to a general education, has made it more or less the subject of study, and is frequently better acquainted with its structure and properties than the medical practitioner. Complicated as its organization may seem, it is, in action, characterized by extreme simplicity; yet, "in its simplicity," as Arnott has remarked, "so perfect, so unspeakably perfect, that the searchers after tangible evidences of an all-wise and good Creator, have declared their willingness to be limited to it alone in the midst of millions, as their one triumphant proof."

Into this structure we shall inquire, so far as is necessary for our purpose, after having described the general properties of light; and then detail the mode in which its various functions are effected, and the knowledge derived by the mind through its agency.

The eye is the organ of vision. It varies materially in different animals: in some consisting of a simple capsule, with the final expansion of the nerve of sight distributed on its interior, and communicating externally by means of a transparent cornea, which admits the light. It is in this simple state, that M. de Blainville assimilates it to a bulb of hair, modified for the new function it has to perform. In man, and in the upper classes of animals, the organ is much more complicated in its structure; and in it we have a still clearer example of the distinction between the physical, and nervous or vital part of the apparatus, than in any of the other organs of sense—the former consisting of transparent tunics, and humours, which modify the light according to the laws of optics—the latter being a production or expansion of the nervous system, for the reception of the impression of light, and for conveying such impression to the proper part of the encephalon. There is, besides, attached to the organ, a number of accessory parts or *tutamina*, which are more or less concerned in the proper performance of the function. It will be necessary, therefore, to give a succinct view, not only of the eye, properly so called, but also of these accessory organs, which serve to lodge, move, protect, and lubricate it. The description will not, however, be clearly understood, without premising some general observations on the properties of light, especially as regards its refraction, on which the phenomena of vision are greatly dependant.

Of Light.

The sun and the fixed stars are the great sources of light. It is given off also from substances in a state of combustion, and from phosphorescent bodies; and, by entering the eye directly, or after various reflections or refractions, impinges on the optic nerve, and gives the sensation of light.

Two great opinions have been entertained regarding the nature of light: the one, propounded by Newton—that it consists of extremely minute particles, emanating from luminous bodies; the other—that of Descartes, Hook, Huygens, Euler, and others,—that it is a subtile, eminently elastic fluid—an ether—pervading all space, the elastic molecules of which, when put in motion by the internal oscillations of bodies, impress the eye as sonorous vibrations affect the ear. It is not for us to discuss this question of higher physics. We may merely remark, that difficulties attend both hypotheses. According to that of Descartes, it is not easy to explain, why an opaque body should prevent the undulations from reaching the eye,—or the change of direction, which the light experiences in passing from one medium into another; whilst, according to that of Newton, it is difficult to conceive, how a luminous body, as the sun, can shed its immense torrents of light incessantly, without undergoing rapid diminution; and how, with the extreme velocity of light, these particles should not be possessed of sensible momentum; for it has been found, that a large sunbeam, collected by a burning-glass, and thrown upon the scale of a balance of extreme delicacy, is insufficient to disturb the equilibrium. To the hypothesis of Newton it has also been objected, that the particles, being reflected by thousands of bodies, and in innumerable directions, would necessarily jostle and interfere greatly with each other. This objection is not, however, as valid as it appears at first sight. It will be seen hereafter, that the impression of a luminous object remains upon the retina for the sixth part of a second. Admitting it, however, to impress the eye for the $\frac{1}{300}$th part, three hundred particles, per second, would be sufficient to excite a constant and uniform sensation of the presence of light; and since, as we shall find, it traverses sixty-seven thousand leagues in a second of time, if we divide this by three hundred, we shall find a space of six hundred and seventy miles between each particle; a distance equal to that—in a straight line—between New York and Savannah; and if we suppose six particles to be sufficient per second, each will be separated from the other by a space of thirty-three thousand five hundred miles!

Without deciding in favour of either of the great theories, that of Newton admits of more easy application to our subject, and will, therefore, be employed in the various explanations that may be required.

The light, then, proceeding from a luminous body, impinges on the substances, that are within its sphere; and these, by reflecting the whole or a part of it to the eye, become visible to us.

In its course, direct or reflected, its velocity is almost inconceivable. From observations made on the eclipses of Jupiter's satellites, by Römer, Cassini, and other astronomers, it has been calculated, that the light of the sun is eight minutes and thirteen seconds in its passage from that luminary to the earth. The distance between the earth and sun is thirty-three millions of leagues, so that the velocity of light is sixty-seven thousand leagues, or two hundred thousand miles per second; in other words, in the lapse of a single second it could pass between Washington and Albany—supposing the distance to be three hundred miles—seven hundred times; and could make the tour of the globe in the time it takes us to wink. In consequence of this extreme velocity,—in all calculations, regarding the light from bodies on the surface of the globe, it is presumed to reach the eye instantaneously; for, granting that a luminous body at Albany could be seen at Washington, the light from it would reach the eye in the $\frac{1}{700}$th part of a second. Inconceivable as this velocity is, it is far surpassed by that of the attractive power exerted between the heavenly bodies. "I have ascertained," says La Place, "that between the heavenly bodies all attractions are transmitted with a velocity, which, if it be not infinite, surpasses several thousand times the velocity of light; and we know that the light of the moon reaches the earth in less than two seconds." An annotator on the works of this distinguished mathematician is more definite, affirming, "that the gravific fluid passes over one million of the earth's semi-diameters in a minute of time." Its velocity is eight millions of times greater than that of light.

A series of particles, succeeding each other in a straight line, is called a *ray* of light. The light which proceeds from a radiant point, forms diverging *cones*, which would be prolonged indefinitely did they not meet with obstacles.

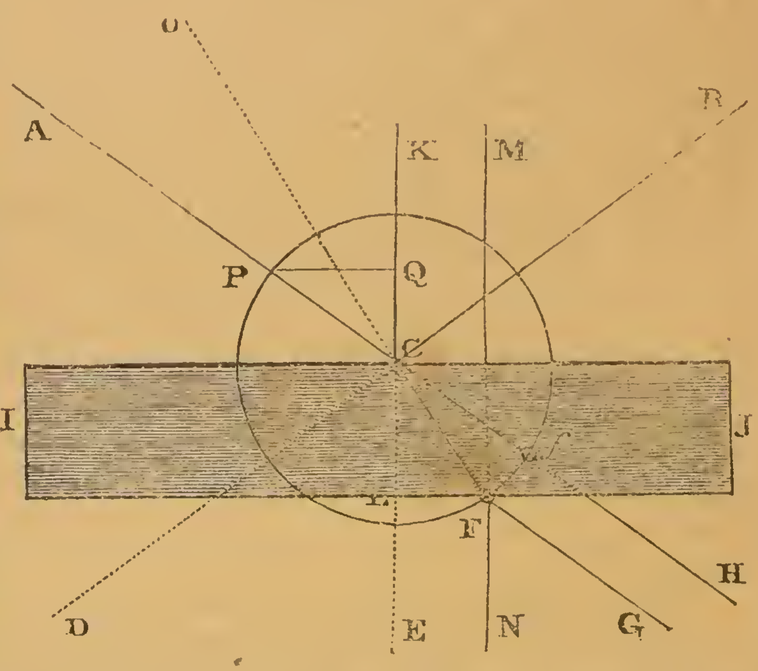
In its course, it loses its intensity according to a law, which seems applicable to all influences radiating from a centre. If a taper be placed in the middle of a box, each of whose sides is a foot square, all the light must impinge upon the sides of the box If, afterwards, it be placed in a box, whose sides are two feet square, the light will shine upon them from double the distance, but it will be distributed over four times the surface. The intensity of the light, then, in this case, as in every other, diminishes according to the square of the distance from the luminous body. According to this rule, those planets, which are nearer to the sun than we are, must receive the light and also the heat—for the same law applies to caloric—in much greater intensity; whilst the more distant luminaries can receive but little caloric, or light, in comparison with our earth; hence, perhaps, the necessity of the satellites by which they are accompanied, and by whose agency the light of the sun is reflected to the planet, and the deficiency, in some measure, compensated.

In proceeding from a luminous body, the *rays*, *cones*, or *pencils of light* must traverse intermediate bodies, in order to reach the eye. These bodies are called *media*. Air is the common medium; and when, in this way, the light has reached the exterior of the organ, the farther transmission is effected through different transparent humours, which consequently form so many *media*.

In its course through the different media, the light may remain unmodified: it may proceed in the same straight line; or it may meet with an obstacle, which arrests it altogether, or *reflects* it; or, again, it may traverse media of different natures and densities, and be made to deviate from its original course, or be *refracted*.

When a ray of light falls upon an *opaque* body, as upon a bright metallic or other mirror, the light is reflected from the mirror, in such a manner, that the angle, made by the incident ray with a perpendicular to the surface of the medium at the point of incidence, is exactly equal to that made by the reflected ray with the same perpendicular.

Fig. 22.



Suppose I J, (Fig. 22.) to represent a plate of polished metal, or of glass, rendered opaque by a metal spread upon its posterior surface, as in the common looking-glass. The rays, proceeding from an observer at K, will be reflected back to him in the same line K C; that is, in a line perpendicular to C, the point of incidence. The observer will, therefore, see his own image; but, for reasons to be hereafter mentioned, under the head of optical illusions, he will seem to be as far behind the mirror as he really is before it or at E. Suppose, on the other hand, that the observer is at A, and that a luminous body is placed at B; in order that the rays, proceeding from it, shall impinge upon the eye at A, it is necessary that the latter be directed to that point of the mirror, from which a line, drawn to the eye, and another to the object, will form equal angles with the perpendicular; in other words, the angle B C K, or *angle of incidence*, must be equal to the *angle of reflection*, A C K. In this case, again, the object will not appear to be at B, but in the prolongation of the line A C, at H, as far from the point of incidence, C, as B is.

Except in the case of illusions, the study of the reflection of light or *catoptrics* does not concern vision materially. It is on the principles of *dioptrics*, that the chief modifications are effected, in the progress of the light through the physical part of the organ; and, without some knowledge of these principles, the subject would be totally unintelligible. It is necessary, therefore, to dwell at some length on this topic.

Whenever a ray of light passes through *diaphanous* or *transparent* bodies of different densities, it is bent or made to deviate from its course, and such deviation is called *refraction;* the ray is said to be *refracted;* and, owing to its being susceptible of such refraction, is held to be *refrangible.* The point, at which a ray of light enters a medium, is called the *point of immersion;* and that, by which it issues from such medium the *point of emergence.* Instead of considering the medium I J opaque, let us regard it as transparent. C, in this case, will be the point of immersion for the incident rays that meet there; and L and F will be the points of emergence for the rays K E and A C F G, respectively. If a ray of light, as K C, falls perpendicularly on the surface of any medium, it continues its course through the medium without experiencing any modification, and emerges in the same straight line. Hence, a body at L, will appear in its true direction and distance to an observer at K looking directly downwards on a pool of water, I J. If, on the other hand, a ray of light, as A C, after having passed through air, falls obliquely upon the surface of the water at C; by entering a medium of different density, it is deflected from its course; and, instead of proceeding in the direction C H, it is refracted, at the point of immersion, in the direction C F—that is, *towards* the perpendicular K E. If, again, the ray emerges at F into a medium of the same density as that through which it passed in the course A C, it will proceed in a line parallel to A C, or in the direction F G, or it will wander *from* the perpendicular. The cause of this difference in the deflections, produced by different media, is not easy of explanation. The fact, alone, is known to us, that bodies refract light differently according to their densities and nature. If the light proceeds from a rarer to a denser medium it is attracted or refracted *towards* the perpendicular; if, on the contrary, it passes from a denser to a rarer medium, it is refracted *from* the perpendicular. The ray A C passed from a rarer medium,—the air,—into a denser, I J—water: it was refracted in the direction C F, towards the perpendicular K E. On emerging at F, circumstances were reversed; it wandered from the perpendicular M N, and in the direction F G, parallel to A C, because the media, above and below I J, were identical. We can now understand, why water, saline solutions, glass, rock-crystal, &c. have higher refractive powers than air. They are more dense.

The nature or character of bodies also influences greatly their refractive powers. Newton observed this, in his experiments upon the subject, and has furnished science with one of its proudest trophies, by his prognostic, in the then infant state of chemistry, that water and the diamond would be found to contain combustible ingredients. The diamond or *brilliant* is one of the most refractive of known substances, and this is one of the sources of its brilliancy. The opinion of Newton, it is hardly necessary to say, has been triumphantly confirmed.

This refraction of the rays, that fall obliquely upon a medium, gives rise to numerous optical illusions. The ray proceeding from F, in the bent course F C A, will impinge on an eye at A; and the object F will appear to be at *f*. The pool will consequently seem shallower. In like manner, an object O in the air would not be perceptible to an eye in the water at F, in the direction O C F; whilst one at A would be distinctly visible; the ray from it proceeding in the direction A C F, but appearing to come straight to the eye in the direction O C F.

All transparent bodies, at the same time that they refract light, reflect a portion of it. This is the cause of the reflections we notice on the glass of our windows, and of the image perceptible in the eye.

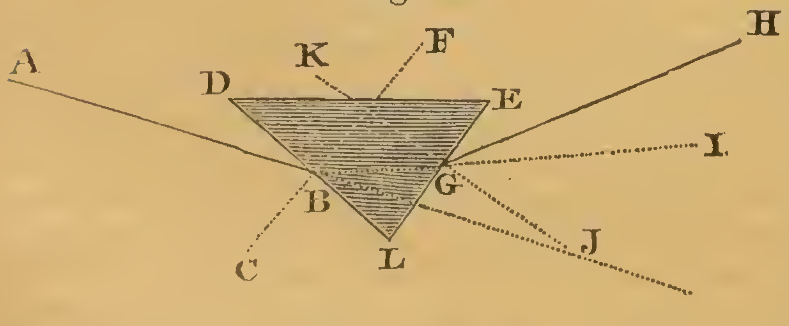
The same substance has always the same refractive power, whatever may be its shape:—in all cases, the sine of the angle of refraction holding the same ratio to the sine of the angle of incidence, whatever may be the incidence. The *angle of incidence* is the angle formed by the incident ray with a perpendicular raised from the point of immersion; the *angle of refraction*, that formed by the refracted portion of the ray with the same perpendicular. In Fig. 22, A C K is the angle of incidence of the ray A C; and L C F the angle of refraction. The sines of these angles respectively are the lines P Q and L F.

But although the media may refract the rays of light equally, the form of the refracting body will materially modify their arrangement. The perpendiculars to the surface may approach or recede from each other; and if this be the case the refracted rays will approach or recede from each other likewise.

Where the body has plane and parallel surfaces, as in the glass of our windows, the refraction, experienced by the ray on entering the glass is corrected by that which occurs on its emergence; and although the light may not pass in one straight line, it proceeds in parallel lines, separated by a space dependent upon the thickness of the refracting body and the obliquity of the incident ray. If the medium be very thin, as in a pane of glass, the rays do not appear deflected from their original direction. In Fig. 19, the interval between the direct ray and the ray A C F after its emergence is that between G and H.

If the surfaces of the diaphanous body are plane, but inclined towards each other, as in the common prism, the refraction, experienced by the ray on emerging, instead of correcting that experienced during its passage through the body, is added to it; and the rays are deflected from their course to an extent equal to the sum of the

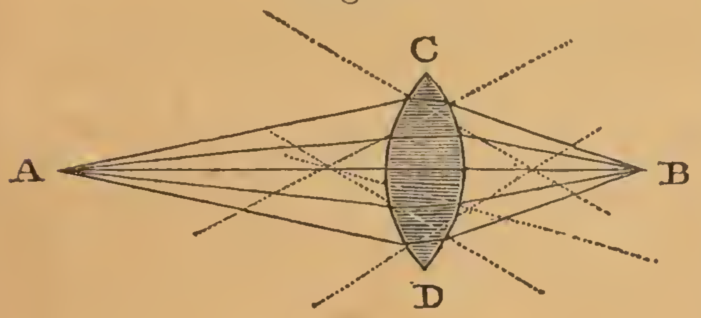
Fig. 23.



two refractions. The ray A B, Fig. 23, after impinging upon the side D L of the prism, at B, instead of continuing its course in the direction B J, is refracted *towards* the perpendicular C B F; the medium being denser than air; and on emerging into the rarer medium, instead of continuing its course in the direction G I, it is refracted in the line G H or *from* the perpendicular K J.

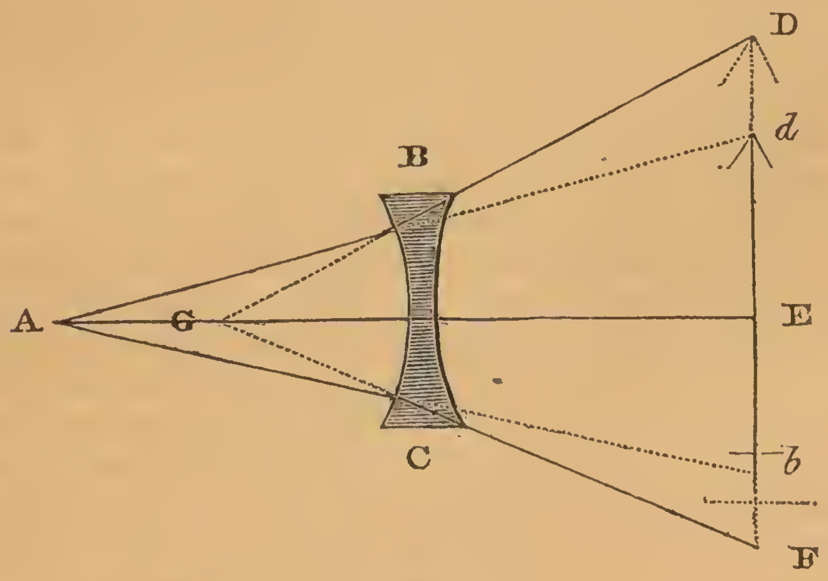
Again, if the surfaces of the medium be convex, the rays are so situated, after refraction, as to converge behind the refracting body into a point called the *focus*, which is nearer to the medium the less the divergence of the rays, or in other words, the more distant the luminous object. Fig. 24 exhibits a pencil of rays, proceeding from a radiant point at A, and meeting at a focus at B; the dotted lines being the perpendiculars drawn to the surface at the points of immersion and emergence.

Fig 24.



Lastly, if the surfaces of the medium be concave, as in Fig. 25, the luminous rays, proceeding from a radiant point as at A, are rendered so divergent, that if we look for a focus here it must be anterior to the medium or at G.

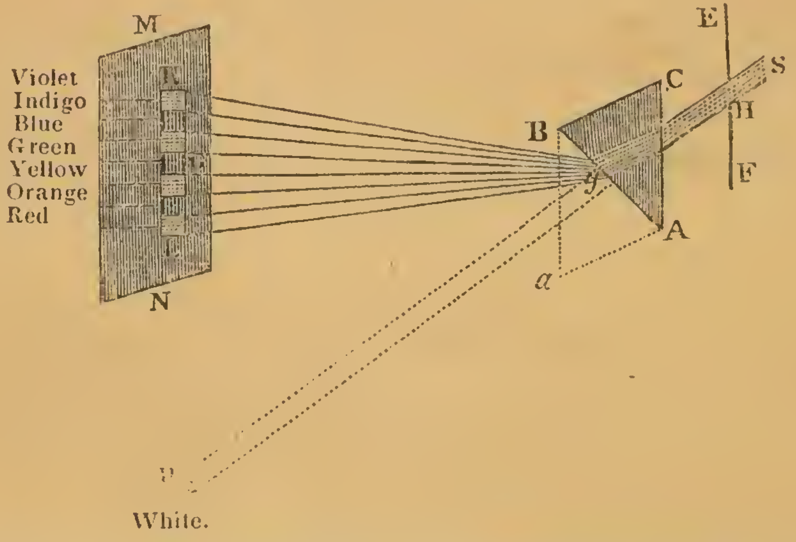
Fig. 25.



A knowledge of these facts has given occasion to the construction of numerous invaluable optical instruments, adapted to modify the luminous rays, so as to change the situation in which bodies are seen, to augment their dimensions, and to render them more luminous, and visible, when remote and minute. It is, indeed, to this branch of science that we are indebted for some of the most important information and advantages, that we possess in the domains of science and art. The simplest of these instruments are bodies, shaped like a lentil, and hence called *lenses.* They are composed of two segments of a sphere. The medium in Fig. 24 is a *double convex lens;* that in Fig. 25, a *double concave.* The manner in which they modify the course of the luminous rays, passing through them, has been sufficiently described.

The study of the refraction of light leads us to the knowledge of an extremely important fact; which, when it was first made known by Newton, excited universal astonishment;—viz. that a ray of light is itself composed of several coloured rays, differing from each other in their refrangibility.

Fig. 26.



If a beam of the sun's light be admitted through the hole of a window-shutter, E F, into a dark chamber, it will proceed in a direct line to P, and form a white spot upon the wall, or on a whitened screen placed there for the purpose. But if a glass prism, B A C, be placed, so that the light may fall upon its surface, C A, and emerge at the same angle from its second surface, B A, in the direction *g* G; the beam will expand; and if, after having emerged, it be received on the whitened screen, M N, it will be found to occupy a considerable space; and, instead of the white spot, there will be an oblong image of the sun, K L, consisting of seven colours;—*red, orange, yellow, green blue, indigo,* and *violet.* Each of these colours admits of no farther decomposition, when again passed through the prism; and the whole lengthened image of the sun is called the *prismatic* or *solar spectrum.*

In this dispersion of the coloured rays, it will be observed, that the red ray is the least turned from its course; and is hence said to be the least refrangible; whilst the violet is the most so.

Such is the spectrum, as depicted by Newton: since his time it has, by some, been considered to consist of three colours,—*red*, *yellow*, and *blue*—as certain of the colours can be composed from others,—the green, for example, from the blue and the yellow. Wollaston made it to consist of four; *red*, *green*, *blue*, and *violet:* Sir J. Herschel of four; *red*, *yellow*, *blue*, and *violet:* and, more recently, Sir David Brewster has restricted it to three; *red*, *yellow*, and *blue*. The causes which have led to these various divisions, it is not our province to explain.

Each of the rays, of which the spectrum is composed, appears to have a different calorific and chemical action; but this is a subject, that nowise concerns the function we are considering.

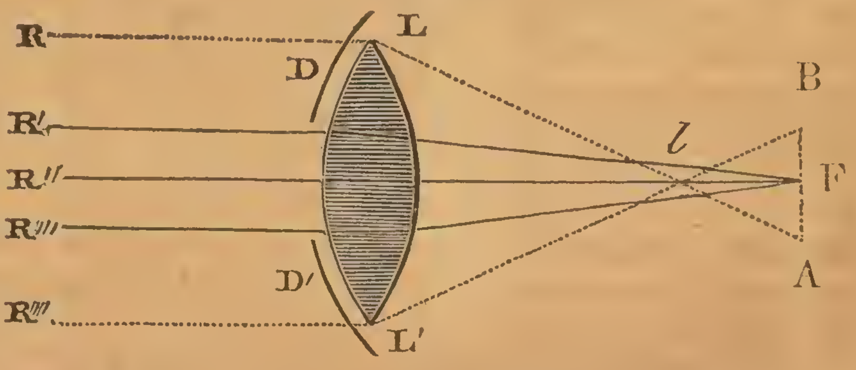
The decomposition of light into its constituent rays enables us to explain the cause of the colour of different substances. When white light impinges upon a body, the body either absorbs all the rays that compose it; reflects all; or absorbs some, and reflects others. If it reflects the whole of the light to the eye, it is of a *white* colour; if it absorbs all, or reflects none, it is *black;* if it reflects only the red ray, and absorbs all the rest, it is *red*, and so of the other colours.

The cause, why one body reflects one ray, or set of rays, and absorbs others, is totally unknown. It is conceived to be owing to the nature and particular arrangement of its molecules. This is probable. But we are still as much in the dark as ever. It is accounting for the *ignotum per ignotius*.

Two other points require a brief notice, being intimately concerned in vision;—the *aberration of sphericity*, and the *aberration of refrangibility*.

It has been remarked, that the rays of light—after passing through a convex lens, or medium whose surfaces are convex—converge, and are brought to a focus behind it. The whole of the rays do not, however, meet in this focus. The rays that are nearest the *axis*, R″ F of the lens, Fig. 27, are refracted to a focus more remote from the lens, than those that fall on the lens at a distance from the axis.

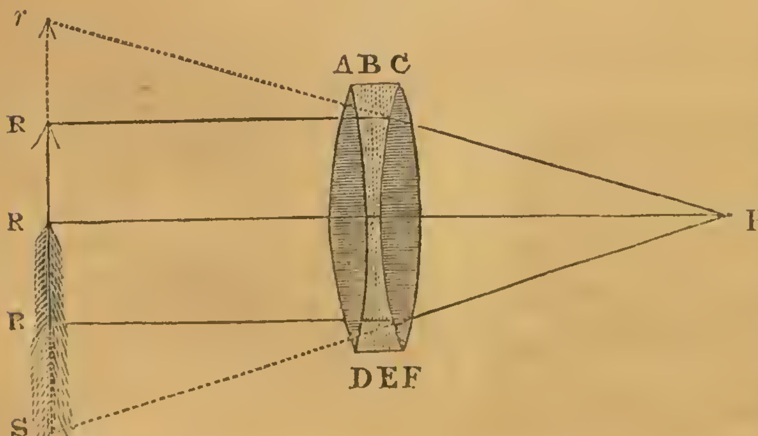
Fig. 27.



The rays R′, R″, and R‴, are brought to a focus at F, whilst the rays R L, and R″″ L′ converge at the point *l*, much nearer the lens. In like manner, rays, which fall upon the lens intermediate between the rays R and R′, will have their foci intermediate between *l* and F. This diversity of focal distances is called the *spherical aberration*, or the *aberration of sphericity:* the distance *l* F is the *longitudinal spherical aberration;* and B A the *lateral spherical aberration*, of the lens. This aberration is the source of confusion in common lenses; and, as it is dependant upon the shape of the lens, it has been obviated, by forming these instruments of such degrees of curvature, that the rays, falling upon the centre or margins of the lens, may all be refracted to the same focus. This is effectually accomplished by lenses, whose sections are ellipses or hyperbolas. In a common lens, the inconvenience is obviated by employing lenses of a small number of degrees, or by interposing an opaque body—called, by the opticians, a *diaphragm*—anterior to the lens, so that the rays of light can only impinge upon the central part, and consequently be refracted to the same focus. This diaphragm is present in all telescopes, and occupies the situation of the curves D and D′ in Fig. 27, so as only to admit the rays R′, and R″, and R‴, to fall upon the lens. Such an apparatus, we shall find, exists in the human eye.

Lastly,—it has been already observed, that the different rays, constituting the solar spectrum, are unequally refrangible,—the red being the least, the violet the most so; hence the cause of their dispersion in the spectrum. It follows from this fact, that, whenever light experiences refraction, there must be more or less dispersion of its constituent rays; and the object, seen by the refracted ray, will appear coloured. This must, of course, occur more particularly near the margins of the lens, where the surfaces become less and less parallel until they meet. The inconvenience, resulting from this dispersion, is called the *aberration of refrangibility*, and it has been attempted to be obviated by glasses, which have been termed, in consequence, *achromatic*. These are made by combining transparent bodies of different dispersive powers, in such sort, that they may compensate each other, and thus the object be seen in its proper colours, notwithstanding the refraction. Dr. Blair found, for example, that by enclosing muriate of antimony, B E, between two convex lenses of crown glass, A D and C F, the parallel rays R, R and R were refracted to a single focus at P without the slightest trace of secondary colour. Newton was of opinion, that the light, in traversing a refracting medium, always experiences a dispersion

Fig. 28.



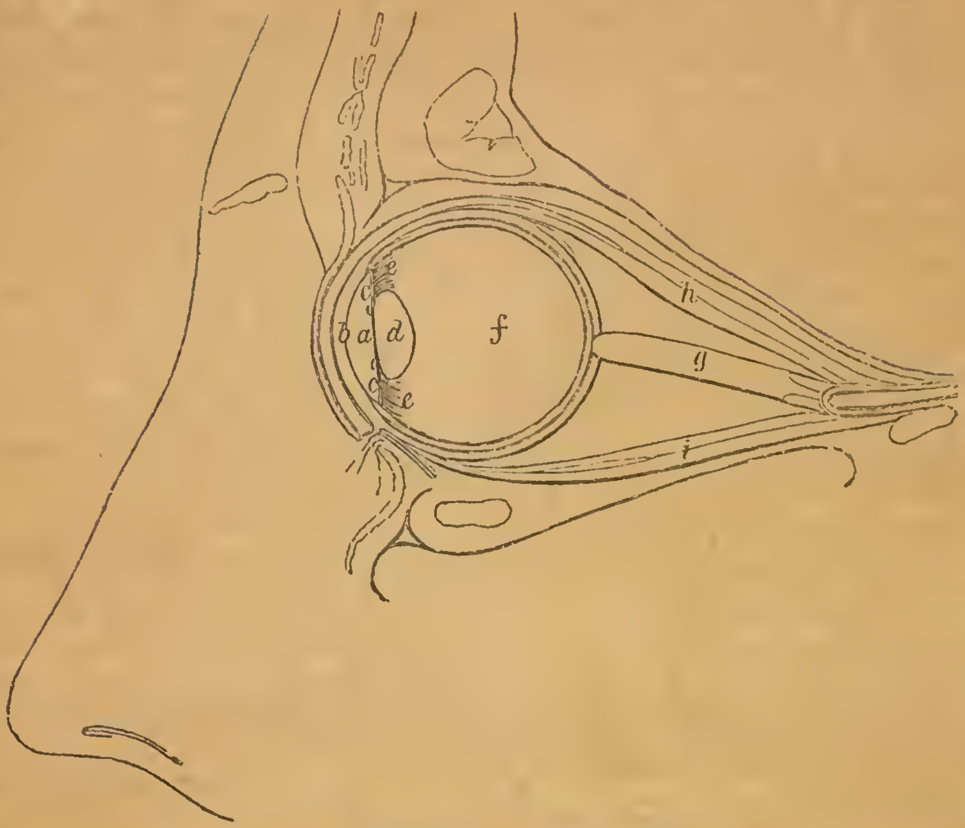
of its rays, proportional to its refraction. He therefore believed, that it would be impossible to fabricate an achromatic glass. This is one of the rare cases in which that illustrious philosopher erred. Since his time,—and chiefly by the labours of Dollond,—such instruments have been formed on the principles above mentioned; so as to greatly diminish the inconveniences sustained from the use of common lenses; although, still, not perfectly *achromatic*. The inconvenience is farther obviated by the diaphragm in telescopes, already referred to. As the dispersion is most experienced near the margin of the lens, it shuts off the rays, which would otherwise fall upon that portion, and diminishes the extent of aberration. The human eye is achromatic. It is obviously essential that it should be so; and this result is probably owing to a combination of causes. It is formed of media of different dispersive powers. Its lens is constituted of layers of different densities, and it is provided with a diaphragm of singularly valuable construction.

Such are the prominent points of the beautiful science of optics, that chiefly concern the physiologist, as an introduction to vision. Others will have to be adverted to, when we consider the eye in action.

Anatomy of the Organ of Vision.

The human eye is almost spherical, except for the prominence of its most anterior and transparent part—the *cornea*. It has been compared to a telescope, and with much propriety; as many of the parts of that instrument have been added, to execute particular offices, which are admirably performed by the eye—the most perfect of all optical instruments.

Fig. 29.



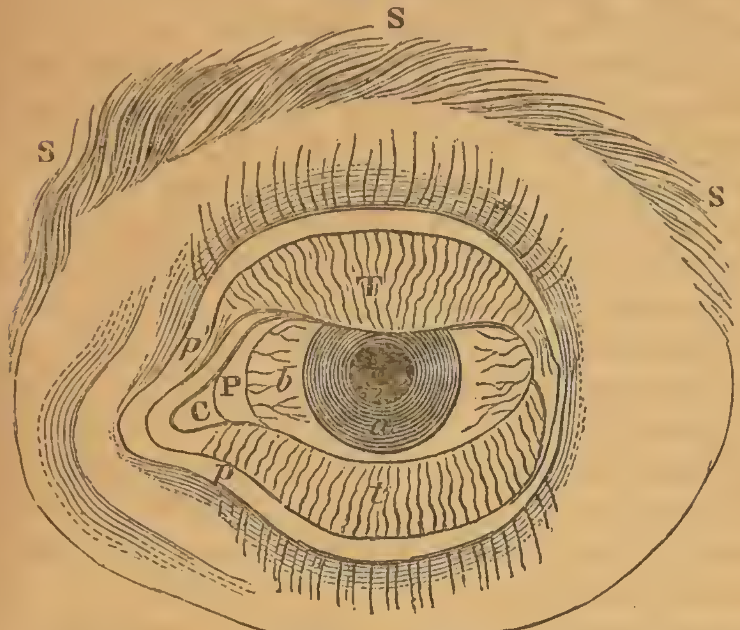
a. Aqueous humour.—*b.* Cornea.—*c.* Iris.—*d.* Lens.—*e.* Ciliary processes.—*f.* Vitreous humour.—*g.* Optic nerve.—*h. i.* Muscles above and below.

Every telescope consists, in part, of a tube, which always comprises pieces, capable of readily entering into each other. Within this cylinder are several glasses or lenses, placed in succession from one extremity to the other. These are intended to refract the rays of light and to bring them to determinate foci. Within the telescope is a kind of partition of paper or metal, having a round hole in its centre, and usually placed near a convex glass, for the purpose of diminishing the surface of the lens accessible to the rays of light, and obviating the spherical aberration. The interior of the tube and of the diaphragm is coloured black, to absorb the oblique rays, which are not inservient to vision, and thus to prevent them from causing confusion.

This arrangement is nearly a counterpart of that, which exists in the eye. The tube of the instrument is represented by three membranes in superposition,—the *sclerotic*, *choroid*, and *retina;* the latter being the one, that receives the impression of light. Within this case are four refracting bodies, situated one behind the other; and all intended to bring the rays of light to determinate foci, viz.—the *cornea*, *aqueous humour*, *crystalline lens*, and *vitreous humour*. Lastly, in the interior of the eye, near the anterior surface of the crystalline lens, is a diaphragm—the *iris*, having an aperture in its centre—the *pupil*. These different parts will demand a more detailed notice.

1. *Coats of the eye*, &c.—The *sclerotic* is the outermost coat. It is that which gives shape to the organ, and which constitutes the *white of the eye*. It is of a dense, resisting, fibrous nature, belonging to what Chaussier calls the *albugineous* tissue. Behind, it is penetrated by the optic nerve; and before, the cornea is dovetailed into it. It has, by some anatomists, been considered a prolongation of the dura mater, accompanying the optic nerve; whilst the choroid has been regarded as an extension of the pia mater, and the retina, of the pulp of the nerve. The sclerotic is the place of insertion for the various muscles that move the eyeball, and is manifestly intended for the protection of the internal parts of the organ.

Fig. 30.



a. Iris.—*b.* White of the eye.—P. Plica semilunaris.—C. Caruncula lachrymalis.—S S S. Supercilium.—T. Under surface of upper eyelid.—*t.* Under surface of lower eyelid.—*p.* Punctum lachrymale in the tarsus of each eyelid.

Immediately within the sclerotica—and feebly united with it by vessels, nerves and cellular tissue—is the *choroid coat;*—a soft, thin, vascular, and nervous membrane. It completely lines the sclerotic, and has consequently the same shape and extent. Behind, it is perforated by the optic nerve; before, it has the iris united with it; and within, it is lined by the retina, which does not however adhere to it,—the black pigment separating them from each other. It is chiefly composed of the ciliary vessels and nerves, and consists of two distinct laminæ, to the innermost of which Ruysch—the son—gave the name *membrana Ruyschiana*. In fishes these laminæ are very perceptible, being separated from each other by a substance, which Cuvier considers to be glandular. The choroid is impregnated and lined by a dark-coloured mucous pigment, called *pigmentum nigrum*. In some cases, as in the *albino*, this substance, which is exhaled from the choroid, is light-coloured, approximating to white. Leopold Gmelin conceives, that it approaches the nature of indigo; whilst Dr. Young regards it as a mucous substance, united to a quantity of carbonaceous matter, upon which its colour depends. On the outer side of the bottom of the cavity of the eye, there is a small shining space, destitute of this pigment, through which the colours of the membrana Ruyschiana appear. This spot is termed the *tapetum*. It is met with only in quadrupeds.

The *retina* is the last coat, if we except a highly delicate serous membrane,—lately discovered by Mr. Jacobs, Demonstrator of Anatomy in Trinity College Dublin, and called after him *Tunica Jacobi*,—which is interposed between the retina and choroid coat. Mr. George H. Fielding, of Hull, has also recently affirmed, that immediately behind the retina, and in connexion with it, there is a peculiar membrane, separable into distinct layers from the choroid, and supplied with blood-vessels, which he proposes to name *membrana versicolor*. He presumes, that it receives the vibrations of light, and communicates them to the retina. The eyes, used for experiment, were those of the ox and the sheep. The retina lines the choroid; and is a soft, thin, pulpy, and grayish membrane, formed chiefly, if not wholly, by the final expansion of the optic nerve. Ribes, indeed, esteems it a distinct membrane, on which the optic nerve is distributed;—a structure more consistent with analogy. On its inner surface, it is in contact with the membrane of the vitreous humour, but they are not adherent. Anteriorly, it terminates near the anterior extremity of the choroid, forming a kind of ring, from which an extremely delicate lamina is given off. This is reflected upon the ciliary processes, dips into the intervals separating them, and, according to some anatomists, passes forward as far as the crystalline. About a sixth of an inch on the outside of the optic nerve, and in the direction of the *axis* of the eye, or of a line drawn perpendicularly through the centre of the cornea, is a *yellow spot*, about a line in extent, surrounded by several folds, and having a foramen in its centre. These are the *limbus luteus*, and *foramen centrale* of Sömmering.

The retina receives many blood-vessels, which proceed from the *central artery of the retina*, or *of Zinn*. This vessel—it is important to observe—enters the eye through the centre of the optic nerve; and, before passing directly through the vitreous humour, sends off lateral branches to the retina.

2. *Diaphanous parts of the eye.*—The parts, which act as refracting bodies, are either transparent membranes, or fluids contained in capsules, which give them a fixed shape. These parts are the *cornea*, *aqueous humour*, *crystalline*, and *vitreous humour*.

The *cornea* is the convex transparent part of the eye, advancing in front of the rest of the organ, as a watch-glass does before the case, and appearing like the segment of a smaller sphere superadded to a larger. It was, for a long time, considered to be a prolongation of the sclerotic; but they are manifestly distinct membranes, being separable by maceration. The posterior surface is concave, and, between it and the iris, is the small space occupied by the aqueous humour, called the *anterior chamber of the eye*. The cornea is composed of several thin laminæ in super-position, which have been compared to horn, and hence the name of the membrane. Like the corneous tissue in general, it possesses neither blood-vessels nor nerves. In animals, the density and convexity of the cornea vary with the media in which they exist, and with the condition of the other refractive parts of the eye.

The *aqueous humour* is a slightly viscid fluid, which occupies the whole of the space between the posterior surface of the cornea and the anterior surface of the crystalline. This space is divided by the iris into two chambers—an *anterior* and a *posterior*—the latter being the small interval between the hinder surface of the iris, and the anterior surface of the crystalline. Sir David Brewster erroneously asserts that the *posterior chamber* contains the crystalline and vitreous humours; and Dr. Arnott, that the anterior and posterior chambers of the eye, are the compartments before and behind the crystalline. Anatomists are not agreed, whether the aqueous humour has a proper membrane, which secretes it, or whether it is not an exhalation from the vessels of the iris and ciliary processes. Ribes, indeed, derives it from the vitreous humour. However secreted, it is very rapidly regenerated, when evacuated; as it must be in every operation for the cataract by extraction. It is not lodged in cells, and hence readily flows out when the cornea is punctured. The quantity of aqueous humour, in the adult, is about five or six grains. Its specific gravity is not rigidly established, but it differs slightly from that of water, being a little greater. According to Berzelius, it is composed of water 98.10; a little albumen, muriates, and lactates 1.15; soda, with a substance soluble in water, 0.75.

Fig. 31.

Section of the eye magnified three diameters.

The *crystalline lens* is a small body, of a crystalline appearance, and lenticular shape, whence its name. It measures, in the adult, about 1.33 of an inch in its greatest circumference; and is about $2\frac{1}{2}$ lines thick at its centre. It is situated between the aqueous and vitreous humours, and at about one-third of the antero-posterior diameter of the organ. A depression, at the anterior surface of the vitreous humour, receives it, and a reflection of the proper membrane of this humour passes over it.

The crystalline is surrounded by its *capsule*, the interior of which is bathed by a slightly viscid and transparent secretion, called *liquor Morgagni*. The lens is more convex behind than before; the radius of its anterior surface being, according to Brewster, 0.30 of an inch; and that of its posterior surface 0.22 of an inch. It consists of a number of concentric ellipsoid laminæ, increasing in density from the circumference to the centre. Some fibres detach themselves from the different laminæ to those immediately beneath, constituting the sole bond of union that exists between them.

Of old, it was believed, that the crystalline was of a muscular structure, and capable of modifying its own convexity, so as to adapt the eye to distances. This was the opinion of Descartes; and it has more recently been revived, with modifications, by Dr. Young. Its muscularity is, however, by no means established, although its fibrous character is unquestionable.

The specific gravity of the human crystalline is said, by Chenevix, to be 1.0790. He considered it to be composed chiefly of albumen: according to an analysis, however, of Berzelius, it would appear to contain 35.9 parts, in the hundred, of a matter very analogous to the colouring matter of the blood.

The *vitreous humour*, so called in consequence of its resemblance to melted glass, occupies the whole of the cavity of the eye behind the crystalline. It is convex behind, and concave before, and is invested by a delicate, thin, transparent membrane, called *tunica hyaloidea*, which furnishes prolongations internally, that divide it into cells. It is owing, indeed, to this arrangement of the membrane, and not to the density of the humour, that it has the tenacity of the white of egg. Its density does not differ materially from that of the aqueous humour;—their specific gravities being stated at 1.0009, and 1.0003 respectively. The cells, formed by the hyaloid membrane, are not all of the same shape and size. They communicate freely with each other, and are well represented in Fig 31.

At the anterior part, where the hyaloid membrane reaches the margin of the crystalline, it is separable into two laminæ; one of which is reflected over the anterior, the other over the posterior surface of the lens. Between these laminæ, and at their junction round the crystalline, a canal exists, into which air may be introduced; when it exhibits a plaited arrangement, and has hence been called the *bullular canal of* Petit; and, by the French writers, the *canal goudronné*, or simply, the *canal of* Petit. This canal is generally conceived to be devoid of aperture; but Jacobson affirms, that it has, in its sides, a number of minute foramina, which admit the entrance and exit of the aqueous humour.

The composition of the vitreous humour, according to Berzelius, is as follows:—water, 98.40; albumen, 0.16; muriates and lactates, 1.42; soda, with an animal matter, soluble only in water, 0.02. Its absolute weight is fifteen or twenty times greater than that of the aqueous humour.

3. It was remarked, in the comparison drawn between the eye and the telescope, that a diaphragm exists in the former, called the *iris*; and sometimes the *uvea*. Generally, however, the latter term is appropriated to the posterior lamina of the iris. By some anatomists, the iris is conceived to be a prolongation of the choroid: by others, to consist of a proper membrane, of a muscular character; and, by others again, to be essentially vascular and nervous; the vessels and nerves being distributed on an erectile tissue. There is, in the views of both anatomists and physiologists, much discrepancy regarding the structure and functions of this portion of

the eye. Edwards, of Paris, affirms, that it consists of four laminæ, two of which are extensions of the laminæ composing the choroid;—a third belongs to the membrane of the aqueous humour, and is reflected over its anterior surface; and the fourth is the proper tissue of the iris. Magendie asserts that the most recent anatomical investigations prove the membrane to be muscular; and to be composed of two sets of fibres;—the outermost radiating; whose office is to dilate the pupil; the innermost circular and concentric, for the purpose of contracting it. The arrangement of these fibres is represented in Figs. 32 and 33; the former of which is an internal view of the human iris, magnified three diameters; and the latter, an external view, exhibiting the surface to consist essentially of a plexus of blood-vessels; both are taken from the microscopic investigations of Mr. Bauer, and Sir Everard Home. These vessels, and the nerves, are ramifications of the ciliary, the nerves arising from the ophthalmic ganglion and nasal branch of the fifth pair.

Fig. 32.

Fig. 33.

The iris is the coloured part of the eye, seen through the transparent cornea; and, according to the particular colours reflected from it, the eye is said to be blue, gray, hazel, &c. In its centre is an opening, called the *pupil*, through which alone the rays of light can reach the lens. This opening can be enlarged or contracted, by the contraction or dilatation of the iris; and in this respect it is perpetually varying, according to circumstances. In man, the pupil is circular, but it differs greatly in its dimensions and shape in different animals.

On the posterior surface of the iris, or on the uvea, the pigmentum nigrum exists, as on the choroid. This layer has likewise some effect in giving colour to the eye. In blue eyes, for instance, the tissue of the iris is nearly white; the pigmentum nigrum, which appears through it, being the chief cause of its colour.

At the point of junction between the iris and the choroid coat, they are united to the sclerotica by a band of cellular substance, called the *ciliary ligament;* and, from the anterior margin of the choroid, where it unites with the base of the iris, numerous vasculo-membranous appendages arise, which appear to be prolongations of the anterior margin of the choroid, turning inwards towards the margin of the crystalline lens, and terminating abruptly, without being attached to that body. They are the *ciliary processes.*

These beautiful appendages are from sixty to eighty in number; and resemble the disk of a radiated flower. On their posterior surface they are covered by the same kind of pigment as that of the choroid and uvea; and they impart the stain to the membranes of the crystalline and vitreous humours. The greatest diversity of opinion, here again, exists regarding both structure and function. By some, these processes have been esteemed nervous; by others, muscular, glandular, and vascular. Sir Everard Home asserts, on the authority of microscopic observations by Mr. Bauer, that between the processes are bundles of muscular fibres of considerable length; which originate all around from the capsule of the vitreous humour, pass forward over the edge of the lens, are attached firmly to its capsule, and there terminate. They are unconnected with the ciliary processes, or iris, and he conceives that their contraction will pull the lens towards the retina. In appearance they resemble the choroid, and are probably identical with it in structure.

Such is an anatomical view of the physical part of the eye proper, so far as is necessary for the physiological inquirer. We have yet to consider the most important part of the organ;—that which is essentially nervous and vital in its action; and which, as we have seen, goes to constitute one of the membranes of the eyeball—the retina.

The *optic nerves*—the *second pair* of Willis—arise from the anterior part of the corpora quadrigemina, and not, as was at one time universally believed, from the *thalami nervorum opticorum*. Setting out from this point, they proceed forwards towards the thalami, to which they adhere; receiving filaments from the *corpus geniculatum externum*, an eminence a little anterior to, and on the outside of, the tubercula; and from a layer of cineritious substance, situated between the point of junction of the nerve of each side and the eminentiæ mamillares,—called the *tuber cinereum*. Proceeding forward towards the eye, the nerves approach, and form a junction at the *sella turcica*, or on the upper surface of the sphenoid bone. Anterior to this point, they diverge, each passing through the optic foramen to the corresponding eye; piercing the sclerotic and choroid at a point about one-tenth of an inch from the axis of the eye on the side next the nose; and expanding, to form the whole, or a part of the retina.

M. Lassaigne has recently examined the chemical composition of the optic nerves and retina; and concludes, from his experiments, that the retina is formed of the same elements as the cerebral and nervous substance; differing only in the proportion of the constituents.

It is a question that has often been agitated, whether the optic nerves, at their junction on the sella turcica, simply lie alongside each other; or whether they do not decussate, so that the root of the nerve of the left eye is on the right side; and that of the right on the left. Anatomical investigations have hitherto left the question unsettled, whilst pathology appears to have furnished proofs on both sides. Thus, where the right eye has been lost for a considerable time, the optic nerve of the *same* side has been found in a state of atrophy through its whole extent. In other cases of the kind, the posterior portion of the *left* nerve has been found in this condition. Fishes have the nerve arising from one side of the brain, and passing to the eye of the other side; hence crossing, but not uniting. On the other hand, Vesalius gives a plate of a case in which he found the optic nerves passing to the eyes of the same side from which they originate without touching at all; and yet without any disturbance of vision. It is not necessary, however, to adduce the numerous cases that have been published in favour of one view or the other. It is impossible to sift those that are entitled to implicit confidence from those that are not. We may merely remark, that certain observations of Valsalva, Cheselden, and Petit appear to show, that where the brain is injured, it is the eye of the opposite side that is affected, and, in cases of hemiplegia or paralysis of one side of the body, we certainly have too many instances for testing the accuracy of this opinion.

Sömmering—whose correctness as an observing anatomist has never been disputed—affirms, that he had an opportunity of examining seven blind persons, in all of whom the atrophy of the nerve was on the side or root opposite to the eye affected. Some, again, have advanced an opinion, that the decussation is partial, and concerns only the internal filaments; that the others pass directly on to half the corresponding eye; so that one-half of each eye is supplied by straight fibres proceeding directly from the root of the same side; the other half by those resulting from the decussation of the internal fibres. Messrs. Wollaston, Bérard, Pravaz, Gall and Spurzheim, Cuvier, Serres, and others, embrace this opinion for the purpose of explaining the anomaly of vision, called *hemiopia*, in which only one-half the object is seen. Cuvier, Serres, and Caldani, also assert, that they have noticed this arrangement in the horse, in the nerves when subjected to appropriate maceration.

These views are, however, opposed by the direct experiments of Magendie. He divided, in a rabbit, the right optic nerve, behind the point of decussation, or what has been called the *chiasma* of the nerves;—the sight of the left eye was destroyed. On cutting the left root, the sight of the right eye was equally destroyed; and on dividing the bond of union by a longitudinal incision, made between the nerves, vision was entirely abolished in both eyes;—a result, which, as he properly remarks, proves not only the existence of decussation, but, also, that it is total, and not partial as Wollaston had supposed. Another experiment, which he instituted, led to a similar result. Fifteen days before examining a pigeon, he destroyed one eye. The nerve of the same side, as far as the chiasma, was wasted; and, behind the chiasma, the root of the opposite side. Rolando and Flourens, too, found in their experiments, that when one cerebral hemisphere was removed, the sight of the opposite eye was lost. We may conclude, then, in the present state of our knowledge, that there is not simply a junction, or what the French call *adossement*, of the optic nerves; but that they decussate at the sella turcica.

The eye proper receives numerous vessels,—the *ciliary arteries and veins*—and several nervous ramifications, the greater part of which proceed from the ophthalmic ganglion of the fifth pair.

The following are the dimensions, &c. of the organ, on the authorities of Petit, Young, Gordon, and Brewster.

		Eng. Inch.
Length of the antero-posterior diameter of the eye		0.91
Vertical chord of the cornea		0.45
Versed sine of the cornea		0.11
Horizontal chord of the cornea		0.47
Size of pupil seen through the cornea		0.27 to 0.13
Size of pupil diminished by magnifying power of cornea to		0.25 to 0.12
Radius of the anterior surface of the crystalline		0.30
Radius of posterior surface		0.22
Principal focal distance of lens		1.73
Distance of the centre of the optic nerve from the *foramen centrale* of Sömmering		0.11
Distance of the iris from the cornea		0.10
Distance of the iris from the anterior surface of the crystalline		0.02
Field of vision above a horizontal line	50° } 120°	
Field of vision below a horizontal line	70°	
Field of vision in a horizontal plane	150°	
Diameter of the crystalline in a woman above fifty years of age		0.378
Diameter of the cornea		0.400
Thickness of the crystalline		0.172
Thickness of the cornea		0.042

It is proper to remark, that all these measurements were necessarily taken from the dead organ, when the parts are by no means in the same relative situation as when alive; and this is a cause, why many of the phenomena of vision can never be determined with mathematical accuracy.

Accessory Organs.

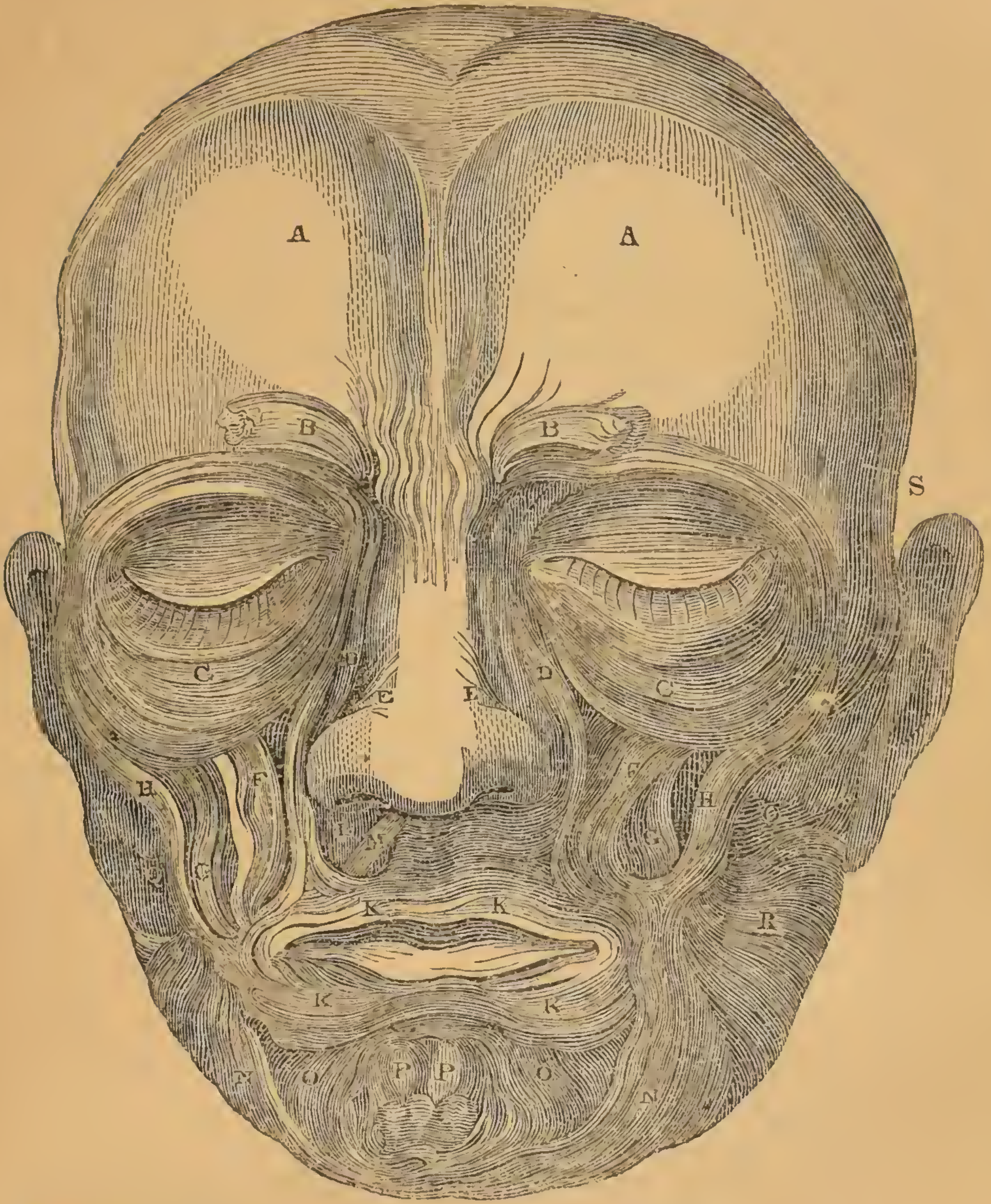
The visual organs, being of an extremely delicate texture, it is of obvious importance, that they should be guarded against deranging influences. They are accordingly provided with numerous parts, which afford them protection, and enable them to execute the functions for which they are destined. They are, in the first place, securely lodged in the bony cavities, called the *orbits*, which are of a conical figure, with the apices directed inwards. In the truncated apex the *foramen opticum* is situated, by which the optic nerve enters the orbit. Here are, also, the *superior orbitar* and *spheno-maxillary fissures*, through which many vessels and nerves proceed to the eye or its appendages. The base of the orbits is not directly opposite to the apices, but tends outwards; so that the axes of these cavities, if prolonged, would meet at the sella turcica. The eye, however, is not placed in the direction of the axis of the orbit, but straight forward; and as it is nearly spherical, it is obvious that it cannot completely fill the conical cavity. In Fig. 29, the muscles *h* and *i* indicate the shape of the upper and lower surfaces of these cavities;—the whole of the space, between the posterior part of the orbit and these muscles, which is not occupied by the optic nerve, being possessed by an adipose, cellular tissue, on which the eye is placed, as it were, on a cushion. Under particular morbid circumstances, this deposit becomes greatly augmented, so as to cause the eye to start from its socket; constituting the disease called *exophthalmos*.

The parts, however, that are more immediately reckoned amongst the protectors of the organ—the *tutamina oculi*—are the *eyebrows*, *eyelids*, and the *lachrymal apparatus*.

The *eyebrows* or *supercilia*, (Fig. 30, S S S.) are situated immediately on the *superciliary* ridge of the frontal bone. They consist of hair, varying in colour according to the individual, and turned towards the outer angle of the eye—of common integument—of subaceous follicles, situated at the root of each hair—and of muscles to move them, namely, the frontal portion of the occipito-frontalis, (A A. Fig. 34;) the upper edge of the orbicularis palpebrarum, C; and the corrugator supercilii, B.

The *palpebræ* or *eyelids* are, in man, two in number, an upper and a lower, or a greater and a less—the *palpebra major vel superior*, and the *palpebra minor vel inferior*—the former covering three-fourths of the eye; hence the transverse diameter of the eye is not represented by their line of union, the latter being much below it, and therefore improperly termed, by Haller, *Æquator oculi*. By the separation of the eyelids, we judge, but inaccurately, of the size of the eye—one, who is capable of separating them more largely from each other, appearing to us to have a larger eye,—and conversely.

Fig. 34.



A A. The frontalis muscle.
B B. Corrugator supercilii.
C C. Orbicularis palpebrarum.
D. Levator labii superioris alæque nasi.
E. Compressor naris.
F. Levator labii proprius.
G. Levator anguli oris.
H. Zygomaticus.
K. Orbicularis oris.
L. Depressor alæ nasi
M. Nasalis labii superioris.
N. Triangularis oris.
O. Quadratus menti.
P P. Levatores menti:
Q. Buccinator.
R. Platysma myoides.
S. Temporalis muscle.

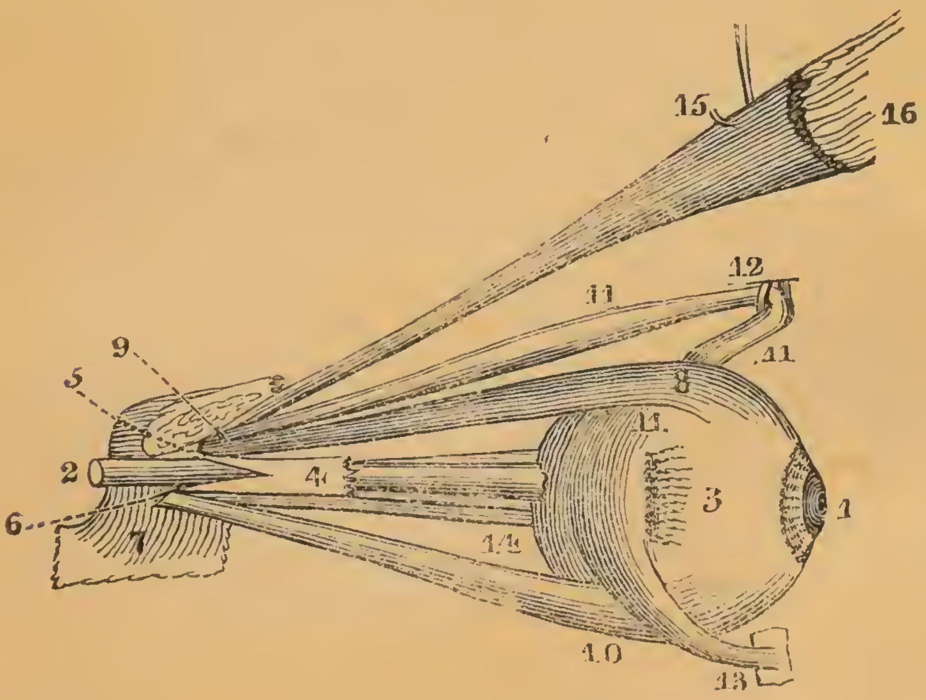
The edge of the eyelids is thick, rounded, and furnished with hairs, resembling generally, in colour, those of the head. These are the *eyelashes* or *cilia*. On the upper eyelid they are curved upwards; on the lower downwards, as in Fig. 30. The eyelids are formed of four membranous layers, in superposition, and of a fibro-cartilage, which extends along the whole of the edge and keeps them tense. The outermost of these layers is the common integument, the skin of which is very delicate and semi-transparent, yielding readily to the motions of the eyelids, and having numerous transverse folds. The cellular tissue, beneath the skin, is very loose, and, under particular circumstances, is infiltrated by a serous, fluid, giving the eyelid, especially the lower, a dark appearance; but it never contains fat. Beneath the common integument is the muscular stratum, formed by the *orbicularus palpebrarum*, (C C. Fig. 34.) in the lower eyelid; in the upper, by the same muscle and the *levator palpebræ superioris*, (Fig. 35,15) which arises from above the foramen opticum, and is inserted into the superior edge of the fibro-cartilage of the tarsus.

Beneath the orbicularis palpebrarum, again, there is a fibrous layer, which occupies the whole of the eyelids, passing from the edge of the orbit to the tarsal margin, and seems intended to limit the motion of the eyelids, when they approximate each other. The last layer, and that which forms the posterior surface of the eyelids, is a fine, delicate, transparent, mucous membrane, called *tunica conjunctiva*, or *tunica adnata;* so named because it joins the eyelids to the globe of the eye. It lines, in fact, the eyelids, and is reflected over the ball; but it has been a matter of contention, whether it passes over the transparent cornea. The generality of anatomists say it does; Ribes, however, maintains the opinion, that it extends only as far as the circumference of the cornea, and that the cornea itself is covered by a proper membrane. Physiologically, this dispute is of no moment. At its outer surface, a humour is constantly exhaled, which keeps it moist, and facilitates the motions of the eyelids over the eyeball. Its loose state also favours these motions. Both eyelids are kept tense by the aid of a fibro-cartilage, situated along the edge of each, and called the *tarsus*. That of the upper eyelid is much more extensive than that of the lower; and both seem as if cut obliquely, at the expense of their inner surface; so that, in the opinion of most anatomists, when the eyelids are brought together, a triangular canal is formed between them and the ball of the eye, which has been conceived useful in conducting the tears towards the lachrymal puncta. Magendie denies that any such canal exists; and there seems but little evidence of it, when we examine how the tarsal cartilages come in contact. Such a canal, destined for the purposes mentioned, would, indeed, seem superfluous. Besides the eyelashes, certain compound follicles are situated in the substance of the tarsal cartilages. These are thirty or forty in number in the upper eyelid, and twenty-five or thirty in the lower. They are in particular furrows between the tarsal fibro-cartilages and the conjunctiva, (Fig 30, T, *t*) and secrete a sebaceous fluid, called by the French *chassie*, in the dry state; by us, *gum of the eye*, which serves the purposes of the follicular secretions in general.

The arrangement of the eyelids differs in different animals. In several, both eyelids move; but, in others, only one; either the lower rising to join the upper, or the upper descending to meet the lower. In the sun-fish—*tetraodon mola*—the eyelid is single and circular, with a perforation in the centre, which can be contracted or enlarged, according to circumstances. In many animals, again, there is a third eyelid, called the *nictitating membrane*, which is of a more delicate texture and more largely supplied with blood-vessels; and in some animals is transparent. In birds it exists, and is well seen in the owl. It is at the inner angle of the eye, and is capable of being drawn over the ball like a curtain, by two particular muscles, and of thus freeing the surface of the eye from extraneous substances. In man, it is only a vestige, destined to no apparent use. It is represented in Fig. 30, and is called *valvula*, or *plica semilunaris*.

The eye has its proper muscles, capable of moving it in various directions. Their arrangement is readily understood. They are six in number:—four *recti* or *straight muscles*, and two *oblique*. 1. The *rectus superior* or *levator*. 2. The *rectus inferior* or *depressor*. 3. The *rectus internus* or *adductor*; and 4, the *rectus externus* or *abductor*. They all arise from the base of the orbit, around the optic foramen; pass forward to vanish on the sclerotica; and, according to some anatomists, extend over, and form a layer to the cornea.

Fig. 35.



1. Globe of the eye.
2. Optic nerve.
3. Aponeurosis of the rectus externus.
4. Posterior extremity of do.
5. One of the origins of do. on the outside of the optic nerve.
6. Inner origin of do. from an aponeurosis.
7. Aponeurosis common to it and the rectus inferior and rectus internus.
8. Rectus superior.
9. Posterior extremity of do.
10. Rectus inferior.
11 11 11. Obliquus superior.
12. Trochlea.
13. Obliquus inferior.
14. Rectus internus.
15. Levator palpebræ superioris.
16. Upper eyelid.

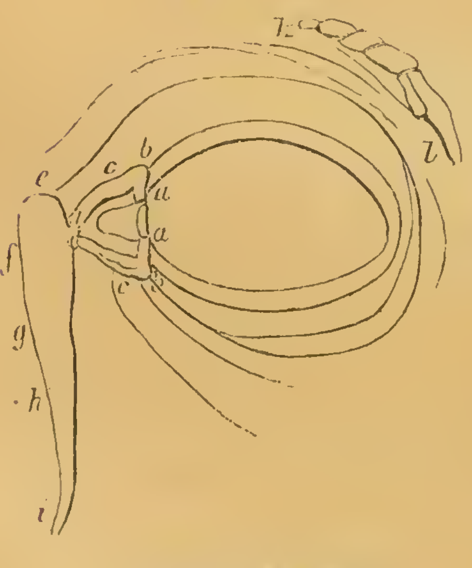
The *oblique muscles* are, 1. The *greater oblique, obliquus superior, patheticus* or *trochlearis* which arises from the inner side of the foramen opticum, passes forwards to the internal orbitar process of the frontal bone, where its tendon is reflected over a pulley or *trochlea*, and crosses the orbit, to be inserted into the upper, posterior, and outer part of the globe of the eye. 2. The *lesser oblique* or *obliquus inferior*, whose fibres arise from the anterior and inner part of the floor of the orbit, near the lachrymal groove, pass under the eyeball, and are inserted between the entrance of the optic nerve and insertion of the abductor oculi, and opposite the insertion of the obliquus superior.

These muscles have their proper nerves. The *third pair—motores oculorum*—or *common oculo-muscular*, are distributed to all the muscles except the trochlearis and abductor. The *fourth pair*, or *pathetic*, or *internal oculo-muscular*, to the trochlearis singly; and the *sixth pair*, or *external oculo-muscular*, to the abductor.

Lastly, the office of *tutamina oculi* is not wholly engrossed by the parts, that have been mentioned. The apparatus for the secretion of the tears participates in it, by furnishing a fluid, which lubricates the surface of the eye, and keeps it in the necessary degree of humidity for the proper performance of its functions. It is a beautifully ingenious little apparatus, the structure of which can easily be made intelligible. It consists of the lachrymal gland, the excretory ducts of the gland, the caruncula lachrymalis, the lachrymal ducts, and the nasal duct; in other words, of two sets of parts—one, forming the fluid and pouring it on the anterior surface of the eye; the other comprising the organs for its excretion.

The *lachrymal gland* is situated in a small fossa or depression at the upper, anterior, and outer part of the orbit. It is an oval body of the size of a small almond; of a grayish colour, and composed of small, whitish, granular bodies collected into lobes. From these, six or seven excretory ducts arise, which run nearly parallel to each other and open on the inner side of the upper eyelid, near the outer angle of the eye and near the tarsal cartilage. Through these ducts, the *tears*, secreted by the lachrymal gland, are spread over the tunica conjunctiva. They are composed, according to Fourcroy and Vauquelin, of water, mucus, muriate of soda, soda, phosphate of lime, and phosphate of soda, and their taste is manifestly saltish, al-

Fig. 36.



a b c d. The lachrymal canals.
a a. The puncta lachrymalia.
e f g h i. The lachrymal duct.
k l. The lachrymal gland.

though the saline ingredients are described as not exceeding a hundredth part of the whole. They are not secreted by those animals that live in water.

At the inner angle of the eye is the *caruncula lachrymalis.* It is a collection of small mucous follicles, which secrete a thick, whitish humour, to fulfil a similar office with the secretion of the meibomian follicles. It completes the circle formed by the meibomian glands around the eyelids. (See Fig. 30.)

The rosy or pale colour of this body is supposed to indicate strength or debility. This it does, like other vascular parts of the system, and in a precisely similar manner.

The *puncta lachrymalia* are two small orifices, situated near the inner angle of the eye; (Fig. 30 & 36,) the one in the upper, the other in the lower eyelid, at the part where the eyelids quit the globe to pass round the caruncula lachrymalis. They are continually open, and directed towards the eye. Each punctum is the commencement of a *lachrymal duct,* which passes towards the nose in the substance of the eyelids, between the orbicularis palpebrarum and tunica conjunctiva. These open, as represented in Fig. 36, into the *lachrymal sac,* which is nothing more than the commencement of the *nasal duct* or *ductus ad nasum.* The bony canal is formed by the anterior half of the os unguis, and by the superior maxillary bone, and opens into the nose behind the os spongiosum inferius. Through these excretory ducts, all of which are lined by a prolongation of the mucous membrane, the tears pass into the nasal fossæ.

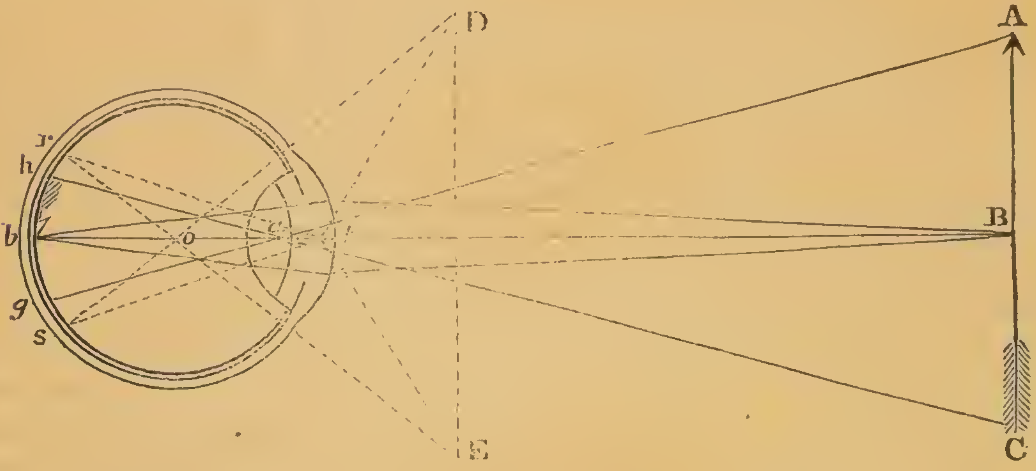
Dr. Horner, the able anatomist, who fills the chair of anatomy in the university of Pennsylvania, has described a small muscle, which is evidently a part of the lachrymal apparatus, and to which he gives the name *tensor tarsi.* It is on the orbital face of the lachrymal sac; arises from the posterior superior part of the os unguis; and, after having advanced a quarter of an inch, bifurcates; one *fork* being inserted along each lachrymal duct, and terminating at or near the punctum. It is probable, that the function of this muscle is to keep the puncta properly directed towards the eyeball, or, as Dr. Physick has suggested, to keep the lids in contact with the globe. The office, assigned to it by Dr. Horner, of enlarging by its contraction, the cavity of the lachrymal sac, and thus producing a tendency to a vacuum, which vacuum can be more readily filled through the puncta than through the nose, owing to the valves or folds of the internal membrane of the sac—is ingenious, but apocryphal.

Physiology of Vision.

The preceding anatomical sketch will enable the reader to comprehend this important organ in action. In describing the office executed by its various components, we shall follow the order there observed, premising some general considerations on the mechanism of vision; and afterwards depicting the protecting and modifying influences exerted by the various accessory parts:—the different phenomena of vision will next be explained, and lastly, the information conveyed to the mind by this sense.

In tracing the progress of luminous rays through the purely physical part of the organ, we shall, in the first instance, suppose a single cone to proceed from a radiant point in the direction of the axis of the eye; or in other words, of the antero-posterior diameter of the organ, B *b*.

Fig. 37.



It is obvious, that the rays, which fall upon the transparent cornea can alone be inservient to vision. Those, which impinge upon the sclerotica, are reflected; as well as a part of those that fall upon the cornea, giving occasion, in the latter case, to the image observed in the eye, and to the brilliancy of the organ. Nor does the whole of the cornea admit the rays, for it is commonly more or less covered, above and below, by the free edge of the eyelids.

Again, the whole of the light, that enters the cornea, does not impinge upon the retina. A portion falls upon the iris, and is reflected back to the eye, in such manner as to give us the notion of the colour of the organ. It is, consequently, the light, which passes through the pupil, that can alone attain the retina.

If we suppose a luminous cone to proceed from the radiant point B, Fig. 37, directly in the prolongation of the antero-posterior diameter of the eye, the axis of this cone will also be the axis of the organ; so that a ray of light, impinging upon the humours in the direction of this axis, will, as in the case of the lenses previously referred to, pass through the humours without undergoing deflection, and will fall upon the retina at *b*. This, however, is not the case with the other rays composing the cone. They do not fall perpendicularly upon the cornea, and are, consequently, variously refracted in their passage through the cornea, aqueous humour, crystalline, and vitreous humour; but so that they join their axis in a focus at the point where it strikes the retina.

The transparent parts of the eye, as has been seen, are of different densities, and are consequently possessed of different refractive powers. These powers it has been attempted to estimate; and the following is the result of the somewhat discordant evaluations of different experimenters: the power of air being 1.000295.

	Cornea.	Aqueous Humour.	Crystalline Lens. Capsule.	Outer Layers.	Centre.	Mean.	Vitreous Humour.
Hawksbee -		1.33595					1.33595
Jurin - -		1.3333					
Rochon -		1.329					1.332
Young - -		1.3333					
Chossat -	1.339	1.338	1.339	1.338	1.393	1.384	1.339
Brewster -		1.3366	1.3767		1.3990	1.3839	1.3394

A ray of light, impinging obliquely on the surface of the transparent cornea, passes from a rarer to a denser medium. It will, consequently, be refracted towards the perpendicular raised from the point of impact. It will, from this cause, as well as from the convexity of the cornea, be rendered more convergent; or, in other words, will approach the axis of the cone. (See Fig. 24.) In proceeding through the aqueous humour, little variation will be produced, as the densities of it and the cornea differ but little: the latter is slightly more refractive, according to the table, and therefore the tendency, that exists, will be to render the ray less convergent. This convergence gives occasion to the entrance of a greater number of rays through the pupil, and necessarily adds to the intensity of the light that impinges on the crystalline. Pursuing the ray through the two chambers of the eye, we find it next impinging on the surface of the crystalline, which possesses a much higher refractive power than the cornea or aqueous humour; in the ratio of 1.384 to 1.336. From this cause, and from the convexity of the anterior surface of the lens, the ray is rendered still more convergent or approaches still more the axis of the cone. It is probable, however, that even here, some of the light is reflected back, and goes towards the formation of the image in the eye, and the brilliancy of the organ; other reflected rays perhaps impinge upon the pigmentum nigrum lining the posterior surface of the iris, and are absorbed by it. From the crystalline the ray emerges into a medium possessing less refractive power; and, therefore, is deflected from the perpendicular. The shape, however, of the posterior surface of the lens so modifies the perpendiculars, as to occasion such a degree of convergence, that the oblique ray meets the axis at a focus on the retina. (See Figs. 24 and 37.) In this manner, two cones are formed; the one having its apex at the radiant point, and its base on the cornea,—the *objective cone*,—the other having its apex on the retina, and termed the *ocular cone*.

These remarks apply chiefly to the cone proceeding in the direction of the axis of the different humours, from a single radiant point. It is easy to understand, that every portion of the object A B C, Fig. 37, must be a radiant point, and project so many cones, in an analogous manner; which, by impinging upon the retina, form a picture of the object upon that expansion, at *g b h*. It is important, however, to observe, that the rays, proceeding from the upper part of the object, fall, after refraction, upon the lower part of the retina; and those from the lower part of the object upon the upper; so that the picture or representation of the object on the retina is inverted. How the idea of an erect object is excited in the mind will be the subject of after inquiry.

When rays fall obliquely on a lens, as A *g* and C *h*, and pass through the centre of the lens, they suffer refraction at each of its surfaces, but as the two refractions are equal and in opposite directions, the rays may be esteemed to pursue their course in a straight line. The point *a*, at which these various rays cross, is called the *optic centre* of the crystalline. Each of these straight rays, proceeding from a radiant point, may be assumed as the axis of all the rays proceeding obliquely from the same point, and the common focus must fall on some part of this axis. In this way, the object is represented, in miniature and inverted, on the retina. As, however, the oblique ray has to pass through the cornea and aqueous humour, before it impinges on the crystalline, it undergoes considerable deflection, and consequently it is not accurate to represent it, as pursuing a straight course through the different humours, in its way to the retina. The main deflection—as in the case of the rays D *t s*, and E *t r*, Fig. 37—occurs at the entrance of the rays into the cornea.

That an inverted representation of external objects is formed within the eye, is in accordance with sound theory, and is supported, not only by indirect, but by direct experiment. If a double convex lens be fitted into an opening, made in the window-shutter of a darkened chamber, luminous cones will proceed from the different objects on the outside of the house, and will converge within; so that if they be received on a sheet of paper, a beautiful and distinct image of the object will be apparent. This is the well known instrument—the *camera obscura*—of which the organ of sight may be regarded as a modification. Making abstraction, indeed, of the cornea, and of the aqueous and vitreous humours, the representation of the eye in Fig. 37, with the object, A B C and its image on the retina, is the common camera obscura. The eye is, therefore, more complicated and more perfect than this simple instrument; the cornea with the aqueous and vitreous humours being added for the purpose of concentrating the light on the retina; the latter, in addition, affording a large space for the expansion of the retina, and preventing the organ from collapsing. In the operation for cataract by extraction, which consists in removing the lens through an opening, made in the lower part of the cornea, the aqueous humour escapes but is subsequently regenerated. If, however, too much pressure be exerted on the ball, to force the crystalline through the pupil and the opening in the cornea, the vitreous humour is sometimes pressed out, when the eye collapses and is irretrievably lost.

Experiments have also been instituted on this subject, the results of which are even more satisfactory than the facts just mentioned. These have been of different kinds. Some experimenters have formed artificial eyes of glass, to represent the cornea and crystalline, with water in place of the aqueous and vitreous humours. Another mode has been to place the eye of an ox or sheep in a hole in the shutter of a dark chamber, having previously removed the posterior part of the sclerotica, so as to permit the images of objects on the retina to be distinctly seen. Malpighi, and Haller employed a more easy method. They selected the eyes of the rabbit, pigeon, puppy, &c. the choroid of which is nearly transparent; and, directing the cornea towards luminous objects, they saw them distinctly depicted on the retina. More recently, Magendie has repeated these experiments by employing the eyes of albino animals, as those of the white rabbit, the white pigeon, the white mouse, &c., which afford great facilities for accomplishing the experiment; the sclerotica being thin, and almost transparent; the choroid, also, thin, and when the blood, which gives it colour, has disappeared after the death of the animal, offering no sensible obstacle to the passage of light. In every one of these experiments, external objects were found to be represented on the natural or artificial retina in an inverted position; the image being clearly defined, and with all the colours of the original. Yet how minute must these representations be in the living eye; and how accurate the mental appreciation, seeing that each impression from myriads of luminous points is transmitted by the retina to the encephalon, and perceived with unerring certainty!

In the prosecution of his experiments—in some of which he was assisted by M. Biot—Magendie found, as might have been expected, that any alteration in the relative proportion or situation of the different humours had a manifest effect upon vision. When a minute opening was made in the transparent cornea, and a small quantity of the aqueous humour permitted to escape, the image had no longer the same distinctness. The same thing occurred when a little of the vitreous humour was discharged by a small incision made through the sclerotica. He farther found, that the size of the image on the retina was proportionate to the distance of the object from the eye.

When the whole of the aqueous humour was evacuated, the image seemed to occupy a greater space on the retina, and to be less distinct and luminous, and the removal of the cornea was attended with similar results.

When the crystalline was either depressed or extracted, as in the operation for cataract, the image was still formed at the bottom of the eye; but it was badly defined, slightly illuminated, and at least four times the usual size.

Lastly:—when the cornea, aqueous humour, and crystalline were removed, leaving only the capsule of the crystalline, and the vitreous humour, an image was no longer formed upon the retina; the light from the luminous body reached it, but it assumed no shape similar to that of the body from which it emanated.

The greater part of these results—as Magendie remarks—accord very well with the theory of vision. Not so, the distinctness of the image under these deranging circumstances. According to the commonly received notions on this subject, it is necessary, in order to have the object depicted with distinctness on the retina, that the eye should accommodate itself to the distance at which the objects is placed; otherwise indistinct vision must result. This is a subject, however, that will be discussed presently.

Such are the general considerations relating to the progress of luminous rays from an object through the dioptrical part of the organ of sight to the nervous portion—the retina. We shall now inquire into the offices executed by the separate parts, that enter into its composition, where they have not already engaged attention.

We have shown, that the *cornea, aqueous humour, crystalline,* and *vitreous humour* are a series of refractive bodies, for concentrating the luminous rays on the retina; to keep the parietes of the eye distended, and to afford surface for the expansion of the retina;—thus enlarging the field of vision. It is probably owing to their different refractive powers, that the eye is achromatic; or, in other words, that the rays, impinging upon the retina, are not decomposed into their constituent colours,—an inconvenience which appertains to the common lens. (Fig. 27.) The eye is strictly achromatic; and it has been an object of earnest inquiry amongst philosophers, to determine how the *aberration of refrangibility* is corrected in it. Euler, first perhaps, asserted, that this is owing to the different refractive powers of the humours; and he conceived, that, by imitating this structure in the fabrication of lenses, they might be rendered achromatic. Experience has shown the accuracy of this opinion, (Fig. 28.) Others have believed, that the effect, is produced by certain of the humours—as the aqueous and the vitreous—which they have considered capable of correcting the dispersion produced by the cornea and crystalline. Others, again, have placed it in the crystalline, the layers of which being of different dispersive powers might correct each other. Lastly—some have denied altogether the necessity for the eye's being achromatic; asserting, that the depth of the organ is so inconsiderable, that the dispersion of the rays, by the time they reach the retina, ought to be inappreciable. Such was the opinion of D'Alembert. Maskelcyne calculated the amount of the aberration, that must necessarily take place in the eye, and concluded that it would be fourteen or fifteen times less than in a common refracting telescope, and therefore imperceptible. Uncertainty still rests on this subject; and it cannot be removed until the dispersive and refractive powers of the transparent parts of the organ be mathematically determined; as well as their exact curvatures. It has been already shown, that the data we possess on this subject from different observers are sufficiently imprecise.

Our knowledge, then, is restricted to the fact, that the eye is perfectly achromatic, and that, in this respect, it exceeds any instrument of human construction. The views of Euler are the most probable; and the effect doubtless is much aided by the iris or diaphragm, which prevents the rays from falling upon the margins of the lens, where, by the surfaces meeting at an angle, the aberration must necessarily be greatest.

Of the *coats of the eye*,—the *sclerotic*, as has been remarked,—gives form to, and protects the organ.

The *choroid* is chiefly useful by the black pigment, which lines, and penetrates it. It will be seen, indeed, that some individuals, on insufficient grounds, have esteemed it the seat of vision. Leaving this question for the moment, and granting, as we shall endeavour to establish, that the impression is received upon the expansion of the optic nerve—the retina—the use of the choroid would seem to be, in ordinary circumstances, to afford surface for the *pigmentum nigrum*, whose function it is to absorb the rays after they have passed through the retina, and thus to obviate the confusion that would arise from varied reflections, were the choroid devoid of such dark covering. In the *albinos* or white animals, in which the pigment is wanting, this inconvenience is really experienced, so that they become *nyctalopes*, or at least see but imperfectly during the day. In the night, however, or when the light is feeble, their vision is unimpaired; and hence the albinos of our species have been called by the Germans and Dutch, kakerlaken, or *cockroaches*.

Sir Everard Home is of opinion, that the pigmentum nigrum of the eye is provided as a defence against strong light, and hence it is lightest in those countries least exposed to the scorching effects of the sun. In confirmation of this, he remarks, that it is dark in the monkey, and in all animals that look upwards, and in all birds exposed to the sun's rays; whilst the owl, that never sees the sun, has no black pigment. The function, assigned to it by Sir Everard, it doubtless possesses, also.

The use of the shining spot on the outside of the optic nerves, in the eyes of quadrupeds, called the *tapetum*, has been an interesting theme of speculation, and has given rise to much ingenious, and to not a little ridiculous, hypothesis amongst naturalists. The absence of the black pigment necessarily occasions the reflection of a portion of the rays from the membrana Ruyschiana; and it has been presumed, that these reflected rays, in their passage back through the retina, may cause a double impression, and thus add to the intensity of vision. Another view has been, that the reflected rays may pass outwards through the retina without exciting any action, to be thrown on the object in order to increase the distinctness of the image on the retina, by an increase of its light. Dr. Fleming, who, in his work on the *Philosophy of Zoology*, usually exhibits much philosophical acumen, and physiological accuracy, thinks it not probable, that both surfaces of the retina are equally adapted for receiving impressions of external objects, and is of opinion, that the rays, in their passage inwards, alone produce the image. More recently, however, M. Desmoulins has adduced many facts and arguments to show, that the tapetum really does act the part of a mirror, and, by returning the rays through the retina, subjects it to a double contact. He affirms, that in nocturnal animals, and in many fishes and birds, which require certain advantages to compensate for the conditions of the media in which they are situated, the tapetum is of great extent, and always corresponds to the polar segment of the eyeball, or to the visual axis; that in many animals, as in the cat, the pigmentum nigrum is wholly wanting; and that it is only necessary for the vision of diurnal animals. He farther remarks, that, in man, the pigment diminishes according to age; and that in advanced life it becomes white; and he ingeniously presumes, that this is a means employed by nature to compensate, in some measure, for the gradual diminution in the sensibility of the retina,—the choroid beneath reflecting more and more of the rays according as the pigment is removed from its surface.

The views of M. Desmoulins are the most satisfactory of any that have been propounded, and they are corroborated by the experiments of Gruithuisen, Esser and Tiedemann, which show, that the phenomenon never occurs when the light is totally excluded. Gruithuisen observed it in the dead as well as in the living animal. Tiedemann perceived it in a cat, which had been decapitated for twenty hours, and it did not cease until the humours had become turbid. The views of these observers impress us the more forcibly, when we compare them with some other fanciful speculations, such as that of M. Richerand, who supposes, that the use of the tapetum is to cause animals to have an exaggerated opinion of *man!* As if the same effect would not be produced whatever were the object that impressed the organ.

The *iris* has been compared, more than once, to the diaphragm of a lens or telescope. Its function consequently must be,—to correct the *aberration of sphericity*, which would otherwise take place. This it does by diminishing the surface of the lens on which the rays impinge, so that they meet at the same focus on the retina. Biot has remarked, that this diaphragm is situated in the eye precisely at the place where it can best fulfil the office, and yet admit the greatest possible quantity of light.

The iris is capable of contracting or dilating, so as to contract or dilate the pupil. It has been already observed, that the views of anatomists, regarding the muscular structure of the iris, have been very discrepant, and that some esteem it to be essentially vascular and nervous, the vessels and nerves being distributed on an erectile tissue. The partisans of each opinion explain the motions of the iris differently. They who admit it to consist of muscular fibres affirm, that the pupil is contracted by the action of the circular fibres, and dilated by that of the radiated. Those, again, that deny the muscularity of the organ, say, that contraction of the pupil is caused by the afflux of blood into the vessels, or by a sort of turgescence similar to what occurs in erectile parts in general, and dilatation by the withdrawal of the surplus fluid.

Admitting, (and we think this must be conceded,) that the iris is really muscular, we meet with a singular anomaly in its physiology—that no ordinary stimulus, applied directly to it, has any effect in exciting it to contraction. It may be pricked with the point of a cataract needle without the slightest emotion being excited; and, from the experiments of Fontana and Caldani, it seems equally insensible, when luminous rays are made to impinge on it; yet MM. Fowler, Rinhold, and Nysten, have proved, that it contracts, like other muscular parts, on the application of the galvanic stimulus. Like them, too, it is under the nervous influence, its movements being generally involuntary; but, there is some reason to believe, occasionally voluntary. Dr. Roget asserts, that this is the case with his eye. In the parrot, and in certain nocturnal birds, its motions are manifestly influenced by volition; and, when the cat is roused to attention, the pupil dilates, so as to allow a greater quantity of light to reach the retina.

Magendie affirms, that the attention and effort, required to see minute objects distinctly, occasion contraction of the human pupil. He selected an individual, whose pupil was very movable; and placing a sheet of paper in a fixed position, as regarded the eye and the light, he marked the state of the pupil. He then directed the person to endeavour, without moving the head or eyes, to read very minute characters, traced on the paper. The pupil immediately contracted, and continued so, as long as the effort was maintained.

Many experiments have been made to discover the nerve, which presides over the movements of the iris. These experiments have demonstrated, that if, instead of directing a pencil of rays upon the iris, we throw it upon the retina, or through the retina on the choroid, contraction of the pupil is immediately induced. The movements of the iris must, then, be to a certain extent under the influence of the optic nerve. It is found, indeed, that if the optic nerve be divided, in a living animal, the pupil becomes immovable and expanded. Yet, that the motions of the iris are not solely influenced by this nerve is evinced by the fact, that in many cases of complete amaurosis of both eyes, there has been the freest dilatation and contraction of the pupil; and also, that the section of the nerve of the fifth pair, which chiefly supplies the iris, equally induces immobility of the pupil. The same effect is produced, according to Mr. Herbert Mayo, by dividing the third pair; and, according to Desmoulins, in the eagle, whose iris is extremely movable, the third pair is the only nerve distributed to the organ.

The general remark, made by Broussais, on the organs that combine voluntary and involuntary functions, is applicable here;—that they will be found to possess both cerebral and ganglionic nerves. Accordingly, Magendie conjectures, that those of the ciliary nerves, which proceed from the ophthalmic ganglion, preside over the dilatation of the pupil, or are the nerves of involuntary action; and that those, which arise from the nasal branch of the fifth pair, preside over the contraction of the pupil. We might thus understand why, in apoplexy, epilepsy, &c., the pupil should be immovably dilated. All volition and every cerebral phenomenon are abolished by the attack; the nerve of the fifth pair, therefore, loses its influence; and the iris is given up to the agency of the ganglionic nerves or nerves of involuntary action, proceeding from the ophthalmic ganglion.

Mr. John Walker, of Manchester, England, considers the iris a third, or internal eyelid, exhibiting the same phenomena of opening and shutting, and the same sensibility to light and other stimuli as the true eyelids. The two sets of fibres, of which the iris is composed, correspond, in his view, to the orbicularis palpebrarum, and the levator palpebræ superioris. The motions of the iris he conceives to be regulated by the ophthalmic ganglion—the branch of the fifth pair probably giving it the power of contracting, whilst its dilating property is attributable to the third pair.

On the whole, as the preceding detail will have sufficiently evidenced, our notions, regarding the motions of the iris, and the nerves that preside over them, are vague and unsatisfactory; and the obscurity is not diminished by a remark of Bellingeri. The iris he observes, derives its nerves from the ophthalmic ganglion, which is formed by the fifth in conjunction with the third pair, and its involuntary motions, he thinks, are regulated by the fifth pair. In those instances, in which the motions of the iris have been found dependent on the will, Bellingeri argues, that the ciliary nerves received no branches from the fifth—a fact, which has been proved by dissection, as well as by the circumstance, that in the parrot, the owl, and the ray genus among fishes—in which the iris is under the will of the animal—there is no ophthalmic ganglion.

The iris contracts or dilates according to the intensity of the light that strikes the eye. If the light from an object be feeble, the pupil is dilated to admit more of the luminous rays; on the contrary, if the light be powerful, it contracts. We see this very manifestly on opening the eyes, after they have been for some time closed, and bringing a candle suddenly near them. It is one of the means we frequently employ in cerebral disease to judge of the degree of insensibility.

We shall presently inquire into the effect of contraction or dilatation of the pupil on distinct vision; and show, that they are actions for accommodating the eye to vision at different distances.

We may conclude, then, that the iris is one of the most important parts of the visual apparatus; and that its functions are multiple:—that it is partly the cause of the achromatism of the organ, by preventing the rays of greatest divergence from falling near the marginal parts of the crystalline:—that it corrects the aberration of sphericity—regulates the quantity of light admitted through the pupil, and accommodates the eye, to a certain extent, to vision at different distances.

An enumeration of the multiform sentiments, entertained regarding the functions of the *ciliary processes*, will show how little we know, that is precise, on this matter also. They have often been considered contractile; some believing them connected with the motion of the iris, others to vary the distance of the crystalline from the retina. Jacobson makes them dilate the apertures, which he conceives to exist in the *canal goudronné*, so as to cause the admission of a portion of the aqueous humour into the canal, and thus to change the situation of the crystalline. Others believe, that they secrete the pigmentum nigrum; and others—the aqueous humour. But the processes are wanting in animals, in which the humours, notwithstanding, exist. There is no opinion, perhaps, more probable than that of Haller;—that they are destined to assist mechanically in the constitution of the eye, and have no farther use.

The function of the *retina* remains to be considered. It is the part that receives the impression from the luminous rays, which impression is, by the optic nerve conveyed to the brain. This nervous expansion was, at one time, universally believed to be the most delicately sensible membrane of the animal frame. Of late, it has been shown by the experiments of Magendie, that the sensibility of both it and the optic nerve is almost entirely *special*, and limited to the appreciation of light;—that the *general* sensibility is exclusively possessed by the fifth encephalic pair, and that the nerve of special sensibility is incapable of executing its functions, unless that of general sensibility be in a state of integrity. That distinguished physiologist found, when a couching needle was passed into the eye at its posterior part, that the retina might be punctured and lacerated without the animal exhibiting evidences of pain. The same result attended his experiments on the optic nerves. These nerves, both anterior and posterior to their decussation, as well as the thalami nervorum opticorum, the superficial layer of the tubercula quadrigemina, and the three pairs of motor nerves of the eye gave no signs of general sensibility. On the other hand, the general sensibility of the anterior part of the eye—of the conjunctiva—is well known. It is such, that the smallest particle of even the softest substance excites intense irritation. This general sensibility Magendie found to be totally annihilated by the division of the fifth pair of nerves within the cranium; so that hard-pointed bodies and even liquid ammonia made no painful impression on the conjunctiva. Nictation was arrested, and the eye remained dry and fixed like an artificial eye behind the paralyzed eyelids. The sight, in this case, also, was almost wholly lost; but by making the eye pass rapidly from obscurity into the vivid light of the sun, the eyelids approximated, and, consequently, some slight sensibility to light remained; but it was extremely slight.

In this sense, then, as in the senses of hearing and smell, we have the distinction between a special nervous system of sense, and a nervous system of general sensibility, without which the former is incapable of executing its elevated functions.

The expansion of the retina occupies at least two-thirds of the circumference of the eyeball. It is of obvious importance, that it should have as much space as possible; and, in certain animals, in which the sense is very acute, the membrane is plaited, so as to have a much larger surface than the interior of the eyeball; and thus to allow the same luminous ray to impinge upon more than one point of the membrane. This is seen in the eyes of the eagle and vulture, and in nocturnal animals. The inconceivable acuteness of the sense of sight in birds of prey, has already been referred to, under the sense of smell. (Page 122.) It was there stated, that the strange facts regarding the condor, vulture, turkey-buzzard, &c., which meet in numbers in the forests, when an animal is killed, ought rather to be referred to acuteness of the sense of sight than of smell. Sir Everard Home affords an additional illustration of this subject. "In the year 1778, Mr. Baber, and several other gentlemen, were on a hunting party in the island of Cassimbusar, in Bengal, about fifteen miles north of the city of Marshedabad; they killed a wild hog of uncommon size, and left it on the ground near the tent. An hour after, walking near the spot where it lay, the sky perfectly clear, a dark spot in the air, at a great distance, attracted their attention; it appeared to increase in size, and to move directly towards them; as it advanced it proved to be a vulture flying in a direct line to the dead hog. In an hour, seventy others came in all directions, which induced Mr. Baber to remark,—this cannot be smell."

How inconceivably sensible to its special irritant must this membrane be in the human eye, when we consider that every part of an extensive landscape is depicted upon its minute surface; not only in its proper situation, but with all its varied tints! and how impracticable is it for us to comprehend, how the infinitely wider range of country can be so vividly depicted on the diminutive eye of the vulture, as to enable it to see its prey from such a remote distance!

If pressure be made on the eyeball, behind the cornea so as to affect the retina, concentric luminous circles will be seen, opposite to the part on which the pressure is applied; and, if the pressure be continued for twenty or thirty seconds, a broad undefined light, which increases in intensity every moment, rises immediately before the eye. If the eyelids be open, and light be present, on the repetition of the last experiment, a dense cloud arises, instead of the broad undefined light, and the eye becomes, in a few seconds, perfectly blind, but, in the course of three or four seconds after the finger is removed, the cloud appears to roll away from before the eye. From this, it seems, that sensations of light may be produced by mechanical pressure made on the retina, in other words, the retina becomes phosphorescent by pressure. The same thing, too, is observed if a sudden blow be given on the eye, or if we place a piece of zinc under the upper lip, and a piece of copper above the eye. A flash of light is seen, produced, doubtless, by the galvanic fluid impressing directly, or indirectly the optic nerve. The same thing occurs in the act of sneezing, and in forcing air violently through the nostrils. On repeating the experiment of pressing the eyeball, Sir David Brewster observed, that when a gentle pressure was first applied, so as to compress slightly the fine pulpy substance of the retina, a circular spot of colourless light was produced, though the eye was in total darkness, and had not been exposed to light for many hours; but if light be now admitted to the eye, the compressed part of the retina is found to be more sensible to the light than any other part, and consequently it appears more luminous. If the pressure be increased, beyond the point mentioned above, the circular part of light gradually becomes darker, and, at length, black, and is surrounded with a bright ring of light. By augmenting the pressure still more, a luminous spot appears in the middle of the central dark one, and another luminous spot diametrically opposite, and beneath the point of pressure. Now, considering the eye, says Sir David, as an elastic sphere, filled with incompressible fluids, it is obvious, that a ring of fluids will rise round the point depressed by the finger, and that the eyeball will protrude all around the point of pressure, and consequently the retina, at the protruded part, will be *compressed* by the outward pressure of the contained fluid, while the retina on each side,—that is, under the point of pressure, and beyond the protruded part,—will be drawn towards the protruded part or *dilated*. Hence the part under the finger, which was originally compressed, is now *dilated*, the adjacent parts are *compressed*, and the more remote parts, immediately without this dilated also. "Now," continues Sir David in his "Letters on Natural Magic"—"we have observed, that when the eye is, under these circumstances, exposed to light, there is a bright luminous circle shading off externally and internally into total darkness. We are led therefore to the important conclusions, that when the retina is compressed in total darkness it gives out light; that when it is compressed, when exposed to light, its sensibility to light is increased; and that, when it is dilated under exposure to light, it becomes absolutely blind, or insensible to all luminous impressions."

Having traced the mode in which the general physiology of vision is effected, and the part performed by each of the constituents of the eye proper, we shall briefly consider the functions of the rest of the visual apparatus; the anatomical sketch of which has been given under the head of *accessory organs;* and afterwards inquire into the various interesting and important phenomena exhibited by this sense.

These organs perform but a secondary part in vision. The *orbit* shelters the eye, and protects it from external violence. The *eyebrows* have a similar effect; and, in addition to this, the hair, with which they are furnished, by virtue of its oblique direction towards the temple, and by the sebaceous secretion that covers it, prevents the perspiration from flowing into the eye, and directs it towards the temple or the root of the nose. By contracting the eyebrows, they can be thrown forwards and downwards in wrinkles; and can thus protect the eye from too strong a light, especially when coming from above.

The *eyelids* cover the eye during sleep, and preserve it from the contact of extraneous bodies. During the waking state, this protection is afforded by the instantaneous occlusion of the eyelids, on the anticipation of danger to the ball. The incessant nictation likewise spreads the lachrymal secretion over the surface of the conjunctiva, and cleanses it; whilst the movement, at the same time, probably excites the gland to augmented secretion.

The chief part of the movement of nictation is performed by the upper eyelid; the difference in the action of the eyelids being estimated, by some physiologists, as four to one. Under ordinary circumstances, according to Adelon, it is the levator palpebræ superioris, which, by its contraction or relaxation, opens or closes the eye; the orbicularis palpebrarum not acting. If the levator be contracted, the eyelid is raised and folded between the eye and orbit, and the eye is open: if, on the other hand, the levator be relaxed, or spread passively over the surface of the organ, the eye is closed. In this view, the orbicularis muscle is not contracted, except in extraordinary cases, and under the influence of volition; whilst the closure of the eye, during sleep, is dependent upon simple relaxation of the levator. The views of Broussais on this subject are, we think, more satisfactory. He considers, that the open state of the eye, in the waking condition, requires no effort; because the two muscles of the eyelids are so arranged, that the action of the levator is much more powerful than that of the orbicularis; and he adduces, in proof of this, that the eyelids are, at the time of death, half open. On the other hand, the closure of the eye in sleep, he conceives to be owing to the contraction of the orbicularis muscle, which acts whilst the others rest. If the opening of the eye were wholly dependent upon the action of the levator palpebræ superioris muscle, its relaxation, during insensibility and death, ought to be sufficient to completely close the eye; and the orbicularis palpebrarum would be comparatively devoid of function; being only necessary for the closure of the organ under the influence of volition.

It has been found by experiments, instituted by Sir Charles Bell, and by Magendie, that nictation is effected under the influence chiefly of the portio dura of the seventh pair, or facial nerve:—one of the respiratory nerves of Sir Charles Bell's system—the *respiratory of the face.* When this nerve is cut, nictation is completely arrested; and when the nerve of the fifth pair, also distributed to these parts, is divided, it ceases likewise, but less thoroughly; a very vivid light exciting it, but only at considerable intervals, and imperfectly.

We see here something very analogous to the partition of the nerves of the senses into those possessing general, and those conveying special sensibility. Like the latter functionaries, the nerve of the seventh pair appears to be *specially* concerned in nictation, and not to be capable of executing its office unless the fifth pair—the nerve of *general* sensibility—be in a state of integrity.

The eyelids, by their approximation, can regulate the quantity of light that enters the pupil, when it is injuriously powerful; when feeble, they are widely separated, to allow as much as possible to penetrate the organ. By their agency, again, the most diverging rays from an object can be prevented from falling upon the cornea; and the vision of the myopic or short-sighted can, in this way, be assisted. It is a means of which they often avail themselves.

The *cilia* or *eyelashes*, it is probable, are of similar advantage as regards the admission of light into the eye, and have some part, probably, in preventing extraneous bodies, borne about in the air, from reaching the sensible conjunctiva.

The *muscles* of the eyeball have acquired the chief portion of their interest of late years, and largely through the investigations of the eminent physiologist—of whose labours we have so frequently had occasion to speak—Sir Charles Bell. The arrangement of the four *straight* muscles, and especially their names, sufficiently indicate the direction in which they are capable of moving the organ, when acting singly. If any two of them contract together, the eyeball will, of course, be moved in the direction of the diagonal, between the two forces; and if each muscle contracts rapidly after the other, the organ will execute a movement of circumduction. The *oblique* muscles are antagonists to each other, and roll the eye in opposite directions; the superior oblique directing the pupil downwards and outwards; the inferior upwards and inwards. But as the different straight muscles are capable of carrying the eye in these directions, were we to regard the two sets of muscles as possessing analogous functions, the oblique would appear to be superfluous.

This, along with other reasons, attracted the attention of Sir Charles Bell to the subject; and the result of his experiments and reflections was:—that the straight muscles are concerned in the motions of the eye excited by volition; and that the oblique muscles are the organs of its involuntary motions; and, in this manner, he accounts for several phenomena, connected with the play of these organs in health and disease.

Whilst the power of volition can be exerted over the recti muscles, the eye is moved about, in the waking state, by their agency; but, as soon as volition fails from any cause, the straight muscles cease to act, and the eye is turned up under the upper eyelid. Hence this happens at the approach of, and during sleep: and whenever insensibility occurs, from any cause, as in faintness, or on the approach of dissolution; and that turning up of the eyeball, which we have been accustomed to regard as the expression of agony, is but the indication of a state of incipient or total insensibility.

Whenever, too, the eyelids are closed, the eyeball is moved, so that the cornea is raised under the upper eyelid. If one eye be fixed upon an object, and the other be closed, with the finger so placed as to feel the convexity of the cornea through the upper eyelid, and the open eye be shut, the cornea of the other eye will be found to be elevated. This change takes place during the most rapid winking motions of the eyelids; and is obviously inservient to the protection of the eye; to the clearing of the eyeball of everything that could obscure vision, and perhaps, as Sir Charles Bell presumes, to procure the discharge from the ducts of the lachrymal gland. During sleep, when the closure of the eyes is prolonged, the transparent cornea is, by this action, turned up under the upper eyelid, where it is securely lodged and kept moist by the secretions of the lachrymal gland and conjunctiva.

The different distributions of the motor nerves of the eye have been described in the anatomical sketch. It was there stated, that the superior oblique muscle receives one whole pair of nerves:—the fourth. This nerve, then, it seemed to Sir Charles Bell, must be concerned in the functions we have described; and, as the various involuntary motions of the eyeball are intimately concerned in expression, as in bodily pain, and in mental agony,—in which the action of the direct muscles seems, for a time, to be suspended,—he was led to consider the fourth pair as a nerve of expression—a respiratory nerve; and, hence, intimately connected with the facial nerve of the seventh pair, which, as has already been remarked, is the great nervous agent in the twinkling of the eyelids. Anatomical examination confirmed this view;—the roots of the nerve being found to arise from the same column as the other respiratory nerves. The coincidence of this twinkling, and of the motion of the eyeball upwards was, therefore, easily understood.

There is a difficulty, however, here, which has doubtless already suggested itself. The fourth pair of nerves is distributed to the superior oblique only; the lesser oblique receives none of its ramifications. They cannot, therefore, be identically situated in this respect. Yet they are both considered by Sir Charles Bell as involuntary muscles. The action, indeed, of the lesser oblique would appear to be even more important than that of the greater oblique, as the function of the former, when acting singly, is to carry the eye upwards and outwards; and, when the action of its antagonist is abolished, this is more clearly manifested. Sir Charles found, that the effect of dividing the superior oblique was to cause the eye to roll more forcibly upwards;—in other words, it was given up, uncontrolled, to the action of the antagonist muscle.

This difficulty, although it is not openly stated by Sir Charles, must have impressed him; as, after having referred to the effect of the division of the superior oblique, he is constrained to suggest an influence to the fourth pair, which would, we think, be anomalous:—that it may, on certain occasions, cause a relaxation of the muscle to which it goes, and, in such case, the eyeball must be rolled upwards! In addition to this, too, as Mayo has observed, the distribution of the muscular nerves of the eye is not such as to allow of our opposing the straight muscles to the oblique, and one cogent reason is, that the third pair of nerves supplies half of each class.

We have still, therefore, much to learn regarding this subject, into which so much interest, and, at the same time, so much uncertainty has been infused. The views of Sir Charles, regarding the functions of the two sets of muscles on certain optical phenomena will be dwelt upon hereafter.

The great use of the *tears* would seem to be to moisten the conjunctiva, and to remove extraneous bodies from its surface,—thus assisting the motions of the eyelids and eyeball, just referred to. These tears are secreted by the lachrymal gland; and, by means of its excretory ducts, they are poured upon the surface of the tunica conjunctiva, at the upper and outer part of the eye. Their farther course towards the puncta lachrymalia has been the subject of difference of sentiment. The generality of physiologists consider, that, owing to the form of the tarsal cartilages, a canal must exist, when the eyelids are closed, of a triangular shape, formed anteriorly by the junction of the cartilages, and behind by the ball of the eye. Magendie, on the other hand, denies the existence of this canal, and asserts, that the tarsal cartilages do not touch by a rounded edge, but by an inner plane surface. If we were to grant the existence of this canal, it could only aid us in our explanation of the course of the tears during sleep. In the waking state, they are not ordinarily secreted in such quantity as to require that much should pass to the puncta;—the movements of nictation spreading them over the surface of the eye, whence they are partly absorbed, and the rest perhaps being evaporated. Under extraordinary circumstances, however, the gland increases its secretion so much, that the tears not only pass freely through the lachrymal ducts into the nose, but flow over the lower eyelid. The *epiphora* or *watery eye*, caused by obstruction of these ducts, also proves that a certain quantity of the secretion must always be passing into the puncta. The physical arrangement of the eyelids and tunica conjunctiva is doubtless the cause of their course in this direction.

It has been gratuitously supposed by some, that the humour of Meibomius prevents the tears from reaching the outer surface of the lower eyelid, by acting like a layer of oil on the margin of a vessel filled with water. A similar function has been assigned to the secretion of the caruncula lachrymalis. Both these fluids, however, are probably inservient to other ends. They are readily miscible with water; become consequently dissolved in the tears, and, with the assistance of the fluid secreted by the tunica conjunctiva, aid the movements of the eyelids over the ball of the eye, and keep the tarsal margins and their appendages in the condition requisite for the due performance of their functions.

The action of the puncta themselves in admitting the tears has received different explanations. Adelon regards it as organic and vital. We ought, however, in all cases, to have recourse to this mode of accounting for phenomena as the *ultima ratio*, and the present appears to us to be a case in which it is singularly unnecessary. In many of the results of absorption we are compelled to suppose, that a vital operation must have been concerned in the process. Where, for example, as in the case of the lymphatic vessels, we find the *same* fluid circulating, whatever may have been the nature of the substances whence it was obtained, the evidence, that a vital action of selection and elaboration has been going on, is irresistible; but no such action can have occurred in the case in question. The tears in the lachrymal ducts and in the ductus ad nasum are identical with those spread upon the surface of the eye; the only difference being in their situation. This is one of the few cases in the human body, which admit of satisfactory explanation on the physical principles of capillary attraction. In vegetables, the whole of the circulation of their juices has been thus accounted for. If we twist together several threads of yarn, moisten them, and put one extremity of the roll into a vessel of water, allowing the other to hang down on the outside of the vessel, and to dip into an empty vessel placed below it, we find, that the whole of the fluid, in the first vessel, is in a short time transferred to the second. If, again, we take a small tube, less than the twentieth part of an inch in diameter, which is called *capillary*, and place it so as to touch the surface of water, we find, that the water rises in it to a height, which is greater the smaller the bore of the tube. If the diameter of the tube be the fiftieth part of an inch, the water will rise to the height of two inches and a half; if the one hundredth part of an inch, to five inches; if the two hundredth part of an inch, to ten inches; and so on. Now, the punctum lachrymale is, in our view of the subject, the open extremity of a capillary tube, which receives the fluid of the lachrymal gland and conveys it to the nose, the punctum being properly directed towards the eyeball by the tensor tarsi muscle of Horner.

Lastly,—the *tunica conjunctiva* is another part of the guardian apparatus of the eye. It secretes a fluid, which readily mixes with the tears, and appears to have similar uses. Like the mucous membranes in general, it absorbs; and, in this way, a part of the lachrymal secretion is removed from its surface. An animal, for the same reason, can be readily poisoned by applying Prussic acid to it. As the conjunctiva lines the eyelids, and is reflected over the globe, it supports the friction, when the eyeball or eyelids are moved; but, being highly polished and always moist, the whole of this is insignificant.

The extreme sensibility of the outer part of the eye appertains entirely to the tunica conjunctiva, and is dependent on the ophthalmic branch of the fifth pair. When this nerve was divided in a living animal, Magendie found, that the membrane became entirely insensible to every kind of contact, even of substances that destroyed it chemically. In his experiments on this subject, he arrived at some singular results, regarding the influence of the fifth pair on the nutrition of the eye. When the trunk of the nerve was divided within the cranium, a little after its passage over the petrous portion of the temporal bone, the cornea was found, about twenty-four hours afterwards, to become troubled, and a large spot to form upon it. In the course of from forty-eight to sixty hours, this part was completely opaque; and the conjunctiva, as well as the iris, was in a state of inflammation; a turbid fluid was thrown out into the inner chamber, and false membranes proceeded from the interior surface of the iris. The crystalline and vitreous humour now began to lose their transparency; and, in the course of a few days, were entirely opaque. Eight days after the division of the nerve, the cornea separated from the sclerotica; and the portions of the humours that remained fluid escaped at the opening. The organ diminished in size, and ultimately became a kind of tubercle, filled with a substance of a caseous appearance. Magendie properly concludes from these experiments, that the nutrition of the eye is under the influence of the fifth pair; and he conceives, that the opacity of the cornea was directly owing to the section of this nerve, and not to a cessation of the lachrymal secretion or to the prolonged contact of air, caused by the paralysis of the eyelids; inasmuch as when the branches of the nerve proceeding to the eyelids were simply divided, or when the lachrymal gland was taken away, the opacity did not supervene.

Phenomena of Vision.

It has been more than once remarked, that the retina—the expansion of the optic nerve—is the part of the eye, which receives the impressions of luminous rays, whence they are conveyed by the optic nerve to the brain. Yet this has been contested.

The Abbé Mariotte discovered the singular fact, that when a ray of light falls, as he conceived, upon the centre of the optic nerve, it excites no sensation.

"Having often observed," he remarks, "on dissections of men as well as of brutes, that the optic nerve does never answer just to the middle of the bottom of the eye; that is, to the place where the picture of the object we look directly upon is made; and that in man it is somewhat higher, and on the side towards the nose; to make therefore the rays of an object to fall upon the optic nerve of my eye, and to find the consequence thereof, I made this experiment. I fastened on an obscure wall, about the height of my eye, a small round paper, to serve me for a fixed point of vision. I fastened such another on the side thereof towards my right hand, at the distance of about two feet, but somewhat lower than the first, to the end that I might strike the optic nerve of my right eye, while I kept my left shut. Then I placed myself over against the first paper, and drew back by little and little, keeping my right eye fixed and very steady on the same, and being about ten feet distant, the second paper totally disappeared."

It is obvious, from what has been said—regarding the axes of the orbits, and the part of the eyeball at which the optic nerve enters—that rays of light from an object can never fall, at the same time, upon the insensible point of each eye. The defect in vision is, consequently, never experienced except in such experiments as those performed by Mariotte. In one of these he succeeded in directing the rays to the insensible point of both eyes at once. He put two round papers at the height of the eye, and at the distance of three feet from each other. By then placing himself opposite them, at the distance of twelve or thirteen feet, and holding his thumb before his eyes, at the distance of about eight inches, so that it concealed from the right eye the paper on the left hand, and from the left eye the paper on the right, he looked at his thumb steadily with both eyes, and both the papers were lost sight of.

These experiments certainly show, that there is a part of the retina or optic nerve, which is, in each eye, insensible to light; and that this point is on the nasal side of the axis. No sooner, however, had Mariotte published an account of his experiments than it was decided, that this spot was the base of the optic nerve; a conclusion was accordingly drawn, that it is incapable of distinct vision, and this conclusion has been embraced, without examination, in almost all the books of optics to the present time. Although probable, however, it is by no means certain, that the light, in these cases, does fall upon the base of the nerve. The direction in which the ray proceeds is such, that it is reasonable to suppose it does impinge there: the suggestion of M. Thilaye, that it falls upon the yellow spot of Sömmering, can only be explained by presuming him to have been in utter ignorance of its situation, which we have seen to be on the outer side of the nerve. But, granting, that the light falls on the base of the nerve, it by no means demonstrates, that the *nerve* is incapable of receiving the impression. It has been already shown, that the central artery of the retina penetrates the eye through the very centre of the nerve; and through the same opening, the central vein leaves the organ. It is probable, therefore, that in these experiments, the ray falls upon the blood-vessels, and not upon the medullary matter of the nerve; and if so, we could not expect that there should be sensation. That the insensible spot is of small magnitude is proved by the fact, that if candles are substituted for the round papers or wafers, the candle does not disappear, but becomes a cloudy mass of light. It is true, Daniel Bernouilli considered the *part* of the nerve insensible to distinct impressions to occupy about the seventh part of the diameter of the eye, or about the eighth of an inch; but there must evidently have been some error in his calculations, for the optic nerve itself can rarely equal this proportion. The estimate of Lecat, who was himself a believer in the views of Mariotte, that its size is about one-third, or one-fourth of a line, is probably still wider from the truth in the opposite direction. Simple experiment, with two wafers placed upon a door at the height of the eye, will show clearly, that both the horizontal and vertical diameters of the spot must be larger than this.

The fact, observed by Mariotte, was not suffered to remain in repose. A new hypothesis of vision was formed upon it; and, as he considered it demonstrated, that the optic nerve was insensible to light, he drew the inference, that the retina was so likewise; and as vision was effected in every part of the interior of the eye, except at the base of the optic nerve, where the choroid is alone absent, he inferred, that the choroid must be the true seat of vision.

The controversy, at one time maintained on this subject, has died away, and it is not our intention to disturb its ashes, farther than to remark, that M. De La Hire, who engaged in it, entertained the opinion, that the retina receives the impression of the light in a secondary way, and through the choroid coat as an intermediate organ: that by the light striking the choroid coat, that membrane is agitated, and this agitation is communicated to the retina. The views of De La Hire are embraced by Brewster, in his recent treatise on optics, as well as by numerous other philosophers.

The opinions of Mariotte have now few supporters. The remarks already made, regarding the optic nerve; the effect of diseases of the retina, of the nerve itself, and of its thalami, compel us to regard its expansion as the seat of vision: and if we were even to admit, with Mariotte, that the insensible portion is really a part of the medullary matter of the nerve, and not a blood-vessel existing there, we could still satisfactorily account for the phenomenon by the anomalous circumstances in which the nervous part of the organ is there placed. The choroid coat, of great importance in the function, is absent; as well as the pigmentum nigrum; and hence we ought not to be surprised, that the function is *imperfectly* executed; we say *imperfectly*, for the experiment with the candles exhibits, that the part is not really insensible to light; or is so in a very small portion of its surface only.

It may seem, at first sight, that the fact of this defect existing only in the centre of the optic nerve, or at the *porus opticus*, as it has been termed, where the central artery of the retina enters, and the corresponding vein leaves the organ, militates against the idea of its being caused by the rays impinging upon these vessels; as, if so, we ought to have similar defects in every part of the retina, where the ramifications of these vessels exist. Circumstances are not here, however, identical. When the ray falls upon the porus opticus, it strikes the vessels in the direction of their length; but, in the other cases, it falls transversely upon them, pierces them, and impresses the retina beneath; so that, under ordinary circumstances, no difference is perceived between the parts of the retina over which the vessels creep, and the remainder of its extent. We can, however, by an experiment described by J. G. Steinbuch, in his *Beitrag zur Physiologie der Sinne*, published at Nürnberg, in 1811, exhibit, that under particular circumstances such difference really exists, and renders the blood-vessels of the organ perceptible to its own vision. If, without closing the eye-lids, the left eye be covered with the hand, or some other body, and a candle or lamp be held in the right hand, within two or three inches of the right eye, but rather below it, (keeping the eye directed straight forward,) on moving the candle slowly from right to left, (or if the candle be held on the right side of the eye, it may be moved up and down,) a spectrum appears, after a short time, in which the blood-vessels of the retina, with their various ramifications are distinctly seen, projected, as it were, on a plane without the eye, and greatly magnified. They seem to proceed from the optic nerve, and to consist of two upper and two lower branches, which ramify towards the field of vision, where a dark spot is seen, corresponding to the foramen centrale. The origin of the vessels is a dark oval spot, with an areola.

This phenomenon must be accounted for by the parts of the retina, covered by the blood-vessels, not being equally fatigued with those that are exposed.

It has been remarked, that the rays, proceeding from the upper part of an object, impinge upon the lower part of the retina; and those from the lower part on the upper portion of the retina; hence, that the image of the object is reversed, as in Fig. 37.

It has, accordingly, been asked;—how is it, that in these circumstances, we see the object in its proper position, inasmuch as its image is inverted on the retina? Buffon, Lecat, and others believed, that originally, we do see them so inverted; but that the sense of touch apprizes us of our error, and enables us to correct it at so early a period, and so effectually, that we are afterwards not aware of the process. Berkeley again asserted, that the position of objects is always judged of, by comparing them with our own; and that, as we see ourselves inverted, external bodies are in the same relation to us as if they were erect. It is not necessary to reply, at length, to these phantasies, which are obviously founded in error. Cases enough have occurred, of the blind from birth having been restored to sight, to show, that no such inversion, as that described by Buffon, takes place; whilst the boy, who stoops down, and looks at objects between his legs, although he may be, at first, a little confused, from the usual position of the images on the retina being reversed, soon sees as well in that way as in any other. The truth is, that the great error with all these speculatists has been, that they have imagined a true picture to be formed on the retina, which is regarded by the mind, and therefore *seen* inverted. It need hardly be said, that there is no interior eye to take cognizance of this image; but that the mind accurately refers the impression, made upon the retina, to the object producing it; and if the lower part of the retina be impressed by a ray from the upper part of an object, this impression is conveyed by the retina to the brain as it receives it, and no error can be indulged.

When a cone of light proceeds from a radiant point, as from B. Fig. 37, the whole of the rays,—whatever may be their relative obliquity,—are, as we have seen, converged to a focus upon the retina at *b*, yet the point B is seen only in one direction, in that of the central ray or axis of the cone B *b*. If we look over the top of a card at the point B, till the edge of the card is just about to hide it; or if, in other words, we obstruct all the rays that pass through the pupil, excepting the uppermost ray, the point is still seen in the same direction as when it was viewed by the whole cone of rays proceeding from B. If we look, again, beneath the card, in a similar manner, so as to see the object by the lowermost ray of the cone, the radiant point will be equally seen in the same direction. Hence, says Sir David Brewster, it is manifest that the line of visible direction does not depend on the direction of the ray, but is always perpendicular to the retina; and, as the surface of the retina is a portion of a sphere, these perpendiculars must all pass through one point, "which may be called the *centre of visible direction;* because every point of a visible object will be seen in the direction of a line drawn from this centre to the visible point."

The point *o*, Fig. 37, is, in Sir David's view, this centre of visible direction. Where a luminous cone proceeds in the direction of the axis of the eye, the centre of visible direction will fall in that line, and a perpendicular, drawn from the point *b*, where the rays of the cone meet at a focus on the retina, will pass through this centre of visible direction *o*, and the same thing, he conceives, will apply to every other pencil of rays. Thus, the rays from D and E, which fall upon the cornea at *t*, will be refracted so as to impinge upon the retina at *s* and *r* respectively, and D and R will be seen in the direction of lines drawn from these points to the centre of visible direction, *o*.

This "law of visible direction," laid down by Sir David Brewster, removes at once, he thinks, every difficulty that besets the subject we have been considering;—the cause of erect vision from an inverted image on the retina. The lines of visible direction necessarily cross each other at the centre of visible direction, so that those from the lower part of the image go to the upper part of the object, and those from the upper part of the image to the lower part of the object.

The views of Sir David are embraced by Mr. Mayo, who considers them confirmed by the fact—to which reference has already been made—that any pressure, made upon the retina through the eyeball, causes a spectrum to be seen in a direction *opposite* to the point compressed, as well as by the following experiments of Scheiners.

If the head of a pin, strongly illuminated, be viewed with one eye at a distance of four inches, that is, within the common limit of distinct vision, the object is seen large and imperfectly defined, the outermost cone of rays, which enters the pupil from each point, being too divergent to be collected to a focus on the retina. If a card, pierced with a pinhole, be now interposed between the eye and the object, the latter may be seen distinctly defined through the pinhole, by means of rays that have entered the pupil nearly parallel, with a slightly divergent tendency. But the object may be seen by rays passing either through the upper or lower part, the right or left side, or the centre of the pupil. Upon shifting the card for this purpose the object appears to move in an *opposite direction*. Or, if three pinholes be made, one in the centre, and one at either side, the object appears tripled; and if one of the side holes be closed, the *opposite* of the three objects disappears: if, for example, the left hand pinhole be closed, the right object disappears.

Again, if the head of a pin, strongly illuminated, be viewed at the distance of eighteen inches, its outline is distinct and clear: the rays, passing from each point of the object, are brought to a point on the retina, but these rays reach the retina at different angles, and, by interposing a card perforated with a single pinhole, the object may be seen by rays, which enter the upper part, or the lower part, or the centre of the pupil. No change, however, in the visual place of the object occurs in this instance, as the card is shifted; nor is the image multiplied, when seen through several pinholes in the card.

The last experiment, says Mr. Mayo, proves, that the angle at which rays of light fall upon the retina, does not affect our notion of the place of objects, and, taken with the preceding, establishes as an inductive law, that *the retina is so constituted, that, however exerted, each point of it sees in one direction only*, that direction being a line vertical to it; or, that in every instance of vision, *each point of an object is seen in the direction of a line vertical, to the point of the retina upon which the rays proceeding from it are collected.*

A certain intensity of light is necessary, in order that the retina may be duly impressed, and this varies in different animals; some of which, as we have seen, are capable of exercising the function of vision in the night, and have hence been termed *nocturnal.* In man, the degree of light, necessary for distinct vision, varies according to the previous state of the organ. A person, passing from a brilliantly illuminated room into the dark, is, for a time, incapable of seeing anything, but this effect varies in individuals; some being much more able to see distinctly in the dark than others. This is owing to the retina, in some, being more sensible than in others; and, consequently, requiring a less degree of light to impress it. On the other hand, a very powerful light injures the retina, and deprives it, for a time, of its function; hence the unpleasant impression produced by the introduction of lights into a room, where the company have been previously sitting in comparative obscurity; or by looking at the sun. The effect upon the retina, thus induced, is called *dazzling.*

If the light that falls upon the eye be extremely feeble, and we look long and intensely upon any minute object, the retina is fatigued; the sensibility of its central portion becomes exhausted, or is painfully agitated; and the objects will appear and disappear, according as the retina has recovered or lost its sensibility; a kind of remission seeming to take place in the reception of the impressions.

These affections are considered by Sir David Brewster as the source of many optical deceptions, which have been ascribed to a supernatural origin. "In a dark night, where objects are feebly illuminated, their disappearance and reappearance must seem very extraordinary to a person whose fear or curiosity calls forth all his powers of observation. This defect of the eye must have been often noticed by the sportsman, in attempting to mark, upon the monotonous heaths, the particular spots where moorgame had alighted. Availing himself of the slightest difference of tint in the adjacent heaths, he endeavours to keep his eye steadily upon it as he advances; but whenever the contrast of illumination is feeble, he almost always loses sight of his mark, or if the retina does take it up a second time, it is only to lose it again."

In all these cases, in which the eye has been so long directed to a minute object, that the retina has become fatigued, on turning the axis of the eye slightly away from the object, the light from it will fall upon a neighbouring part of the retina, and the object will be again perceived; and in the mean time the part, previously in action, will have recovered from its fatigue.

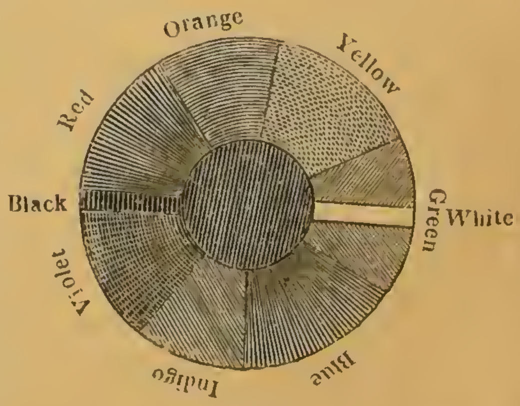
By this fact—of the retina becoming fatigued by regarding an object for a long time—we explain many interesting phenomena of vision. If the eye be directed, for a time, to a white wafer. laid upon a black ground, and afterwards to a sheet of white paper, it will seem to have a black spot, of the same size as the wafer upon it; the retina having become fatigued by looking at the white wafer. On the other hand, if the eye be turned to a black wafer, placed upon a sheet of white paper, and afterwards to another part of the sheet, a portion of the paper, of the size of the wafer, will appear strongly illuminated;—the ordinary degree of light appearing intense, when compared with the previous deficiency.

It is on this, that the whole theory of *accidental colours*, as they are called, rests. When the eye has been, for some time, regarding a particular colour, the retina becomes insensible to this colour; and if, afterwards, it be turned to a sheet of white paper, the paper will not seem to be white, but will be of the colour, that arises from the union of all the rays of the solar spectrum, except the one to which the retina has become insensible. Thus, if the eye be directed for some time, to a *red* wafer, the sheet of paper will seem to be of a *bluish green*, in a circular spot of the same dimensions as the wafer. This bluish-green image is called an *ocular spectrum*, because it is impressed upon the eye and may be retained for a short time; and the colour *bluish-green* is said to be the *accidental colour* of the *red*. If this experiment be made with wafers of different colours, other accidental colours will be observed, varying with the colour of the wafer employed, as in the following table:—

Colour of the wafer.	Accidental colour, or colour of the ocular spectrum.
Red . . .	Bluish-green.
Orange . . .	Blue.
Yellow . . .	Indigo.
Green . . .	Violet, with a little red.
Blue . . .	Orange red.
Indigo . . .	Orange yellow.
Violet . . .	Yellow green.
Black . . .	White.
White . . .	Black.

If all the colours of the spectrum be ranged in a circle, in the proportions they hold in the spectrum itself, as in the accompanying figure,—the accidental colour of any particular colour will be found directly opposite. Hence the two colours have been termed *opposite colours*.

Fig. 38.



It will follow, from what has been said, that if the primary colour, or that to which the eye has been first directed, be added to the accidental colour, the result must be the same impression as that produced by the union of all the rays of the spectrum—that of *white* light.

The accidental colour, in other words, is what the primitive colour requires to make it white light. The primitive and accidental colours are, therefore, *complements* of each other; and hence accidental colours have also been called *complementary colours.* They have likewise been termed *harmonic*, because the primitive and its accidental colour *harmonize* with each other in painting.

It has been supposed, that the formation of these ocular spectra has frequently given rise to a belief in supernatural appearances; the retina, in certain diseased states of the nervous system, being more than usually disposed to retain the impressions, so that the spectrum will remain visible for a long time after the cause has been removed. Such appear to be the views of Drs. Ferriar, Hibbert, and Alderson—the chief writers, in modern times, on apparitions. This subject will be the theme of future discussion. It may be sufficient, at present, to remark, that the great seat and origin of spectral illusions is, in our opinion, the brain, and that the retina is no farther concerned than it is in dreaming or in the hallucinations of insanity. The retina is able to receive visual impressions over its whole surface, but not with equal distinctness or accuracy. When we regard an extensive prospect, that part of it alone is seen sharply, which falls upon the central part of the retina, or in the direction of the axis of the eye; we always, therefore, in our examination of minute objects, endeavour to cause the rays from them to impress this part of the retina;—the distinctness of the impression diminishing directly as the distance from the central foramen increases. This central point, called the *point of distinct vision*, is readily discriminated on looking at a printed page. It will be found that although the whole page is represented on the retina, the letter to which the axis of the eye is directed is alone sharply and distinctly seen; and, accordingly, the axis of the eye is directed in succession to each letter as we read.

In making some experiments on indistinctness of vision at a distance from the axis of the eye, Sir David Brewster observed a singular peculiarity of oblique vision, namely,—that when we shut one eye and direct the other to any fixed point, such as the head of a pin, and hence see all other objects within the sphere of vision indistinctly,—if one of these objects be a strip of white paper, or a pen lying upon a green cloth, after a short time, the strip of paper or the pen will altogether disappear, as if it were entirely removed—the impression of the green cloth upon the surrounding parts of the eye extending itself over the part of the retina, which the image of the pen occupied. In a short time, the vanished image will reappear, and again vanish. When the object, seen obliquely, is luminous, as a candle, it never vanishes entirely, unless its light is much weakened, by being placed at a great distance; but it swells, and contracts, and is encircled with a nebulous halo; the luminous impressions extending themselves to adjacent parts of the retina not directly influenced by the light itself.

From these, and other experiments of a similar character, detailed in his *Treatise of Optics*, Sir David infers, that oblique or indirect vision is inferior to direct vision, not only in distinctness, but from its inability to preserve a sustained vision of objects. Yet it is a singular fact, that the *indirect* has a superiority over *direct* vision in the case of minute objects, such as small stars, which cannot, indeed, be seen by direct vision.

It is a mode, frequently adopted by astronomers for obtaining a view of a star of the last degree of faintness, to direct the eye to another part of the field, and, in this way, a faint star, in the neighbourhood of a large one, will often become very conspicuous, so as to bear a certain illumination, and yet it will entirely disappear, as if suddenly blotted out, when the eye is turned full upon it; and, in this way, it can be made to appear and disappear as often as the observer pleases. Sir J. F. W. Herschel and Sir James South, who describe this method of observation, attempt to account for the phenomenon, by supposing, that the lateral portions of the retina, being less fatigued by strong light, and less exhausted by perpetual attention, are probably more sensible to faint impressions than the central ones; and the suggestion carries with it an air of verisimilitude.

Sir David Brewster, however—from the result developed by his experiments, that, "in the case of indirect vision, a luminous object does not vanish, but is seen indistinctly and produces an enlarged image on the retina, beside that which is produced by the defect of convergency in the pencils,"—concludes somewhat mystically, "that a star, seen indirectly, will affect a large portion of the retina from these two causes, and, losing its sharpness, will be more distinct."

In order, that the image of any object may impress the retina, and be perceived by the mind; it must, first of all, occupy a space on the retina, sufficiently large for its various parts to be appreciated: in the next place, the image must be distinct or sharp; in other words, the luminous rays, that form it, must converge accurately to a focus on the retina: lastly, the image must be sufficiently illuminated. Each of these conditions varies with the size of the body, and the distance at which it is situated from the eye; and there are cases, where they are all wanting, and where the object is consequently invisible.

An object may be so small, that the eye cannot distinguish it; because the image, formed on the retina, is too minute. To remedy this inconvenience, the object must be brought near to the eye, which increases the divergence of the rays and the size of the image; but if we bring it too close to the eye, the rays are not all brought to a focus on the retina, and the image is indistinct. If, therefore, an object be so small, that, at the visual point, to be presently mentioned, the rays, proceeding from it, do not form an image of sufficient size on the retina, the object is not seen. To obviate this imperfection of the sense, minute bodies may be viewed through a small hole in a piece of paper or card, or with the instrument called a *microscope*. By looking through the small aperture in the paper or card, the object may be brought much nearer to the eye; the rays of greatest divergence are prevented by the smallness of the hole from impinging upon the retina; and the rest are converged into a focus upon that membrane, so that a sharp and distinct impression is received. The iris is, in this way, useful in effecting distinct vision; the most divergent rays being—by its contracting the pupil—prevented from falling upon the crystalline.

Any object, that does not subtend an angle of the sixtieth of a degree, is invisible; but it is obvious that the visual power must differ greatly in individuals. Some eyes are much more capable of minute inspection than others; and a greater facility is acquired by practice.

Again, there is a point of approximation to the eye beyond which objects cease to be distinctly seen, in consequence of the rays of light striking so divergently upon the eye, that the focus falls behind the retina. This point, too, varies according to the refractive power of the eye, and is therefore different in different individuals. In the myopic or short-sighted eye, it is much nearer the eye than common; in the presbyopic or long-sighted, more distant. The iris, here again, plays an important part, by its action in shutting off the the most diverging rays, as above described.

There is also a limit beyond which objects are no longer visible. This is owing to the light from the object becoming absorbed before it reaches the retina, or so feeble as not to make the necessary impression. The distance, consequently, at which an object may be seen, will depend upon the sensibility of the retina, and partly on the colour of the object;—a light colour being visible to a greater distance than a darker. A distant object may also be imperceptible, owing to the image, traced on the retina, being too minute to be appreciated, for the image diminishes as the distance of the object increases. The range of distant vision varies, likewise, with the individual, and especially with the myopic and presbyopic; and in such cases the pupil dilates to admit as much light as possible into the interior of the eye, and to compensate in some measure for the defect. Between the ranges of distant and near vision, a thousand different distances occur, which are seen more or less distinctly. In all cases, however, the ocular cone must be brought to a focus on the retina, otherwise there cannot be perfect vision. It has been already observed, in the proem on light, that the distance, at which the ocular cone arrives at a focus behind the lens, is always in proportion to the length of the objective cone; or in other words, that the focus of a lens varies with the distance at which a radiant point is situated before it: where the radiant point is near the lens the focus will be more remote behind it, and the contrary. If this occurs in the human eye it must necessarily follow;—either that it is not necessary, that an object be impressed upon the retina; or that the eye is capable of accommodating itself to distances; or if it does not occur, we must admit, that, owing to the particular constitution of the eye, the impressions are duly made on the retina, without any necessity for such adaptation.

The whole bent of our observations on vision would preclude the admission of the *first* of these postulates. The *second* has been of almost universal reception, and has given rise to many ingenious speculations; whilst the *third* has been seriously urged of late years only.

It would occupy too much space to dwell, at length, upon the various ingenious discussions, and the many interesting and curious experiments, that have resulted from a belief in the power possessed by the eye of accommodating itself to distances. It is a subject, however, which occupies so large a field in the history of physiological opinions, that it cannot be wholly passed over. The chief views, that have been entertained upon the subject, are:—*First.* That the cornea or lens must recede from, or approach the retina, according to the focal distance, precisely as we adapt our telescopes, by lengthening or shortening the tube. *Secondly.* If we suppose the retina to be stationary the lens must experience a change in its refractive powers, by an alteration of its shape or density; or, *Thirdly.* In viewing near objects, those rays only may be admitted, which are nearest to the axis of the eye, and which are consequently the least diverging.

1. The hypothesis, that the adjustment of the eye is dependent upon an alteration in the antero-posterior diameter of the organ, or on the relative position of the humours and retina, has been strongly supported by many able physiologists. Blumenbach was of opinion, and his views seem to have been embraced by Dr. Hosack, that the four straight muscles of the eye, by compressing the eyeball, cause a protrusion of the cornea, and thus an increase in the length of the axis. Dr. Monro believed, that the iris, recti muscles, the two oblique, and the orbicularis palpebrarum have all their share in the accommodation; and Hamberger, Briggs, and others, that the oblique muscles, being thrown in opposite directions around it, may have the effect of elongating the axis of the eye. Kepler thought, that the ciliary processes draw the crystalline forwards, and increase its distance from the retina. Descartes imagined the same contraction and elongation to be effected by a muscularity of the crystalline, of which he supposed the ciliary processes to be the tendons. Porterfield, that the corpus ciliare is contractile, and capable of producing the same effect. Jacobson, that the aqueous humour, by entering the canal of Petit, through the apertures in it, distends the canal, and pushes the crystalline forwards. Sir Everard Home, that the muscular fibres, which he has described as existing between the ciliary processes, move the lens nearer to the retina, and that the lens is brought forward by other means, (which he leaves to conjecture,) when the distance of the object is such as to require its being so.

Dr. Knox, that the annulus albus, or the part which unites the choroid and sclerotic coats, is muscular, and the chief agent in this adjustment; whilst Sir David Brewster thinks it "almost certain, that the lens is removed from the retina by the contraction of the pupil."

Without examining these and other views in detail, it may be remarked, that the nicest and most ingenious examination by the late Dr. Young could not detect any change in the length of the axis of the eyeball. To determine this, he fixed his eye, and at the same time forced in upon the ball the ring of a key, so as to cause a very accurately defined phantom to extend within the field of perfect vision; then looking to bodies at different distances, he expected, if the figure of the eye were modified, that the spot, caused by the pressure, would be altered in shape and dimensions; but no such effect occurred; the power of accommodation was as extensive as ever, and there was no perceptible change either in the size or figure of the oval spot.

Sir Everard Home, again, asserts, that all the ingenuity of the distinguished mechanician, Ramsden, was unable to decide, whether, in the adjustment of the eye, there is any alteration produced in the curvature of the cornea.

These facts would alone induce a doubt of the existence of this kind of adjustment, even if we had not the additional evidence, that many animals are incapable of altering the shape of the eyeball, by the muscles at least. The cetacea and the ray, amongst fishes,—and the lizard amongst reptiles, have the sclerotica so inflexible as to render any variation in it impossible.

With regard to many of the particular views that have been mentioned, they are mere "cobwebs of the brain," and unworthy of serious argument. In the action of the orbicularis palpebrarum, as suggested by Dr. Monro, there is, however, something so plausible, that many persons have been misled by it.

He made a set of experiments to show, that this muscle, by compressing the eyeball, causes the cornea to protrude, and thus enables the eye to see near objects more distinctly. When he opened his eyelids wide, and endeavoured to read letters, which were so near the eye as to be indistinct, he failed; but when he kept the head in the same relation to the book, and brought the edges of the eyelids within a quarter of an inch of each other, and then made an exertion to read, he found he could see the letters distinctly. But on this experiment Sir Charles Bell properly remarks, that if the eyelids have any effect upon the eyeball by their approximation, it must be to flatten the cornea; and that the improvement in near vision produced by such approximation, was owing to the most divergent rays being shut off, as in the experiment of the pin-hole through paper, and distinct vision being thus effected.

2. The second hypothesis, which attributes the adaptation to a change of figure in the crystalline itself, has been embraced by all

those who regard that body to be muscular; and therefore by Leeuwenhoek and Descartes, and more lately by Dr. Young.

These muscular fibres, however, could never be excited by Dr. Young, so as to change the focal power; and their existence is more than doubtful. The increasing density of the lens towards the centre indicates rather a cellular structure, the cells being filled with transparent matter of various degrees of concentration; and an examination into its intimate physical constituents affords no evidence of muscularity.

It is somewhat singular, that on a subject where so many opportunities have occurred for establishing the fact definitively, such difference of opinion should exist regarding the question, whether an eye from which the crystalline has been removed, as in the operation for cataract, is capable of adjusting itself to near objects? Amongst others, Haller, and Knox decide the question affirmatively; Porterfield, Young, and Travers, negatively.

Magendie, as we have seen, considers the great use of the crystalline to be:—to increase the brightness and sharpness of the image by diminishing its size. Mr. Travers again, regards adjustment as a change of figure in the lens; not, however, from a contractile power in the part itself, but in consequence of the lamellæ, of which it is composed, sliding over each other, when acted upon by external pressure; while upon the removal of this pressure, its elastic nature restores it to its former sphericity. The iris is conceived to be the agent in this process; the pupillary part of the organ being, in the opinion of Mr. Travers, a proper sphincter muscle, which, when it contracts and relaxes, will tend, by the intervention of the ciliary processes, to effect a change in the figure of the lens, which will produce a corresponding change in its refractive power.

3. One of the causes, to which the faculty of seeing at different distances has been ascribed, is the contraction and dilatation of the pupil. It has been already observed, that when we look at near objects, the pupil contracts, so that the most divergent rays do not penetrate the pupil, and the vision is distinct. Hence it has been conceived probable—by De La Hire, Haller, and others—that the adjustment of the eye to various distances, within the limits of distinct vision, may be effected by this mechanism, in the same manner as it regulates the quantity of light admitted into the interior of the organ. Certain it is, that if we look at a row of minute objects, extending from the visual point outwards, the pupil is seen to dilate gradually, as the axis of the eye recedes from the nearest object.

An experiment, made by the author, when a student of medicine, on his own eye, has been quoted by Dr. Fleming, as confirmatory of this view. The extract of belladonna has the power, when applied to the eyelids, of dilating the pupil considerably. This was so applied, and in the space of about twenty minutes the pupil was so much dilated, that the iris was almost invisible. From the time that it became preternaturally dilated, objects, presented to this eye with the other closed, were seen as through a cloud. The focus was found to be at twice the distance of that of the sound organ; but, in proportion as the effects of the belladonna went off, and the pupil approached its natural size, vision became more and more distinct, and the focus nearer the natural. In the open air, all objects, except those near, were distinctly seen, but, on entering a room, all was enveloped in mist.

There is, indeed, more evidence in favour of the utility of contraction and dilatation of the pupil in distinct vision, within certain limits at least, than of either of the other supposed methods of adjustment; and, accordingly, the majority of opticians of the present day embrace this view of the subject; but without being able to explain satisfactorily the change in the interior of the eye effected by its movements. "It seems difficult," says Sir David Brewster—the latest writer on this subject, "to avoid the conclusion, that the power of adjustment depends on the mechanism, which contracts and dilates the pupil; and as this adjustment is independent of the variation of its aperture, it must be effected by the parts in immediate contact with the base of the iris. By considering the various ways, in which the mechanism at the base of the iris may produce the adjustment, it appears to be almost certain, that the lens is removed from the retina by the contraction of the pupil." The conclusion, drawn by Sir David, does not, however, impress us with the same degree of certainty.

Pouillet, in his lectures before the *Faculté des Sciences* of Paris, explains the matter with no little confidence, by the double effect of the crystalline being composed of different layers, and the mobility of the pupil. These layers being thinner towards the axis of the crystalline than near its edges, by detaching them successively, the curvature of the remainder becomes greater and greater, until the most central portion has the shape of a sphere. Hence, he remarks, such an apparatus will not have one focus only, but several, —as many, in fact, as there are superposed layers;—the foci being nearer and nearer as we approach the central spherical portion. This arrangement, he says, enables us to see at all distances, inasmuch as, having "an infinite number of foci at our disposal, we can use the focus, that suits the object we are desirous of viewing." If, for example, it be a near object, the pupil contracts, so as to allow the rays to fall only on the central parts; if more distant, the pupil is dilated to permit the rays to pass through a part, that has a more distant focus.

It is obvious, however, that in such a case, the ordinary inconvenience of the aberration of sphericity must result; as when the pupil is dilated, the rays must pass through the more marginal, as well as through the central parts of the lens. Pouillet himself is aware of this difficulty, but he does not dispose of it philosophically. "It may be said," he remarks, "that in opening the pupil widely, the light is not precluded from passing by the centre, and that a kind of curtain would be required to cover the part of the lens, which is unemployed. To this I reply, that there is no necessity to prevent the rays from passing by the axis of the crystalline; for, what is the light, which passes through this small space compared with that which passes through the great zone of the crystalline. It may be looked upon as null."

The whole affair, it must be admitted, is enveloped in perplexity, and it is rendered not the less so by the fact, mentioned by Magendie, that if we take the eye of an albino animal, and direct it towards a luminous object, we find a perfect image depicted on the retina, whatever may be the distance of the object;—the image, of course, being smaller and less luminous when remote, but always distinct. Yet, in this experiment, the eye being dead, there could be neither contraction nor dilatation of the pupil.

This result has induced Magendie—and not too hastily, we think—to draw the conclusion—that although theory may suggest, that there ought to be such adaptation, as has been presumed and attempted to be accounted for, observation proves, that this is not the fact; and, consequently, all the speculations on the subject, however ingenious they may be, must fall to the ground.

We are, indeed, not justified, perhaps, in admitting more than a slight accommodation from the contraction of the pupil in viewing near objects, effected in the mode already explained. If the accommodation existed to any material extent, it is difficult to understand, why trifling cases of short or long-sightedness should not be rectified. Sir Charles Bell conceives, "that the mechanism of the eye has not so great a power of adapting the eye to various distances as is generally imagined, and that much of the effect attributed to mechanical powers, is the consequence of the motion of the pupil, the effect of light and of attention. An object looked upon, if not attended to, conveys no sensation to the mind. If one eye is weaker than the other, the object of the stronger eye alone is attended to, and the other is entirely neglected: if we look through a glass with one eye, the vision with the other is not attended to." "The mind," he adds, "not the eye, harmonizes with the state of sensation, brightening the objects to which we attend. In looking on a picture or panorama, we look to the figures, and neglect the back-ground; or we look to the general landscape, and do not perceive the near objects. It cannot be an adaptation of the eye, but an accommodation and association of the mind with the state of the impression."

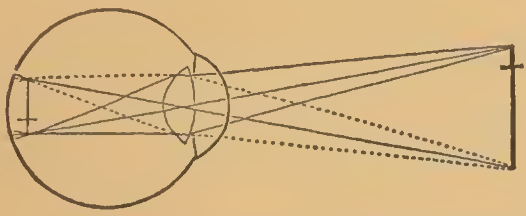
The view, which we have expressed upon the subject, is strikingly confirmed by the calculations of M. De Simonoff, a learned Russian astronomer, who asserts, that from a distance of four inches to infinity, the changes in the angle of refraction do not exceed twenty-three minutes, so that the apices of luminous cones, in a properly formed eye, must always fall within the substance of the retina, and hence no variation in the shape of the eye, according to the distance of the object, can be necessary.

Such facts amply justify the interrogatory of Biot—whether the aberration of the focus for different distances may not be compensated, in the eye, by the intimate composition of the refractive bodies; as the aberration of sphericity probably is? Yet, if this be the case, how admirable must be the construction of such an instrument! how far surpassing any effort of human ingenuity! an instrument capable of not only correcting its own aberration of sphericity, and its aberration of refrangibility, but of seeing at all distances.

It has been before observed, that the *visual point* varies in different individuals. As an average, it may be assumed at eight inches from the eye. There are many, however, who, either from original conformation of the organ, or from the progress of age, wander largely from this average; the two extremes constituting *myopy* or *short-sightedness*, and *presbyopy* or *long-sightedness.*

In the *myope* or *short-sighted*, the visual point is so close, that objects cannot be seen, unless brought near the eye. This defect is owing to too great a refractive power in the transparent parts of the organ; or to too great a depth of the humours; or it may be caused by unusual convexity of the cornea or crystalline; or from the retina being too distant from the crystalline. From any one or more of these causes, the rays of light, proceeding from distant objects, are brought to a focus before they reach the retina, and the objects consequently are not distinctly visible. (Fig. 39.) To see them distinctly, they must be placed close to the eye, in order that the rays may fall more divergently, and the focus be thrown farther back, so as to impinge upon the retina.

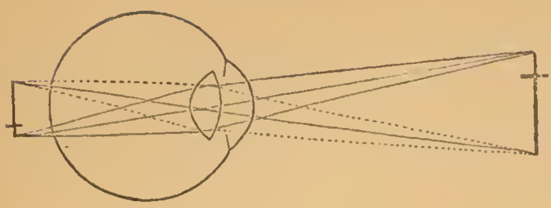
Fig. 39.



The defect may be palliated by the use of concave glasses, which render the rays, proceeding from the object, more divergent. It is by no means infrequent in youth; and the myope has been consoled with the common belief, that, in the progress of life, and in the alterations, that take place in the eye from age, he is likely to see well without spectacles, when others of the same age may find them essential. It is probable, however, that this is, in many cases at least, a vulgar error; as we have known different myopic sexagenarians, who have not experienced the slightest improvement by the progress of age.

The *presbyope*, *presbytic* or *long-sighted* labours under an opposite defect. The visual point is much more distant than the average; and he is unable to see an object unless it is at some distance. This condition is owing to too feeble a refractive power in

Fig. 40.



the transparent parts of the eye; to insufficient depth of the eye; to too close an approximation between the retina and crystalline; or to too little convexity of the cornea or crystalline; so that the rays of light, proceeding from a near object, are not rendered sufficiently convergent to impinge upon the retina, but fall behind it. (Fig. 40.)

This defect, which is experienced more or less by most people, after middle age, is palliated by the use of convex glasses, which render the rays, proceeding from an object, more convergent, and enable the eye to refract them to a focus farther forward, or on the retina.

Although the presbyopic eye is unusual in youth, it is sometimes met with. A young friend, at ten or twelve years of age, was compelled to employ spectacles, adapted to advanced life; and this was the case with several of the members of a family, to whom the arts have been largely indebted in this country. One of them, at twenty, was compelled to wear spectacles which were almost microscopes.

Both the myopic and the presbyopic conditions exist in a thousand degrees, and hence it is impossible to say, *a priori*, what is the precise lens, which will suit any particular individual. This must be decided by trial. The opticians have their spectacles arbitrarily numbered to suit different periods of life, but each person should select for himself such as will enable him to read without effort at the usual distance.

A degree of myopy may be brought on by long-protracted attention to minute and near objects; as we observe occasionally in the watchmaker and engraver; and again, a person, who has been long in the habit of looking out for distant objects, as the sailor, or the watchman at the signal stations, is rendered less fitted for minute and near inspection.

During the domination of Napoleon, when the conscript laws were so oppressive, the young men frequently induced a myopic state of the eye, by the constant use of glasses, of considerable concavity; this defect being esteemed a sufficient ground of exemption from military service.

Another question, which has given rise to much disputation and experiment is, why, as we have two eyes, and the image of an object is impressed upon each of them, we do not see such object double?

Smith, in his "Optics," and Buffon consider, that in infancy we do see it double; and that it is not until we have learned by experience, —by the sense of touch for example,—that one object only exists, that we acquire the power of single vision. After the mind has thus become instructed of its error, a habit of rectification is attained, until it is ultimately effected unconsciously.

The objections to this hypothesis are many and cogent. We are not aware of any instance on record, in which double vision has been observed to occur in those, who, having laboured under cataract from birth, have received their sight by an operation; and we are obviously precluded from knowing the state of vision in the infant, although the simultaneous and parallel motions of the eyes, which is manifestly instinctive, and not dependent upon habit, would induce us to presume, that the images of objects—as soon as the parts have attained the necessary degree of development—are made to fall upon corresponding parts of the retina. This, we shall see, is essential to single vision. It may, also, be remarked, in favour of the instinctive nature of this parallel motion of the eyes, that in the blind,—although we may find much irregularity in the motions of the eyeball, owing to no necessity existing for the eyes being directed to any particular point,—the eyeballs move together, unless some deranging influence be exerted.

Again, are we to presume that all those animals, which are capable of directing their eyes towards the same object, always see double? and if they do not, how is the error rectified in them? Can we suppose, for example, that the young calf sees two mothers, and that it is by an intellectual process, that it knows there is only one?

The truth is, as we have already observed, the encephalon is compelled to receive the impression as it is conveyed to it; and, even in cases, in which we are aware of an illusion, the perception of the illusion still exists in spite of all experience. If the finger be pressed on one side of the eyeball, an object, seen in front, will appear double, and the perception of two objects will be made in the brain; although we know from experience, that one only exists. This occurs in all the various optical illusions to be presently mentioned.

The effect of intoxication has been adduced in favour of this hypothesis. It is said that, in these cases, the usual train of mental associations is broken in upon, and hence double vision results. The proper explanation, however, of this diplopia of the drunkard rests upon other grounds. The effects of inebriating substances on the brain are, to interfere with all the functions of that organ; and most sensibly with the voluntary motions, which become irregularly executed. The voluntary muscles of the eye partake of this vacillation, and do not move in harmony, so that the impressions are not made on corresponding points of the retina, and double vision necessarily results.

Another hypothesis has been, that although a separate impression is made upon each retina,—in consequence of the union of the optic nerves, the impressions are amalgamated, and arrive at the encephalon, so as to produce but one perception.

This was the opinion of Briggs, and Ackermann, and at one time was generally received. Still more recently, Dr. Wollaston has supposed the consentaneous motion of the eyes to be connected with the partial union of the optic nerves. The anatomical and physiological facts, relating to the union and decussation of the optic nerves, have already engaged us. By a reference to that subject it will be found, that a true decussation takes place between them; that each eye has, notwithstanding, its distinct nerve, from origin to termination; and that no such semi-decussation, as that contended for by Dr. Wollaston, exists. These facts are unfavourable to this hypothesis of amalgamation of impressions; and, besides, if we press slightly on the eye, we have a double impression, although the relation of the optic nerves to each other is the same; and, moreover, the same explanation ought to apply to audition, in which we have two distinct impressions, but only a single perception:—yet no one conceives that the auditory nerves decussate.

Another opinion has been maintained;—that we do not actually receive the perception of two impressions at the same time, but that vision consists in a rapid alternation of the eyes, according as the attention is directed to one or other of them by accidental circumstances. Such was the opinion of Dutours. A modification of this view was entertained by Lecat, who asserts, that, although the right eye is not always the most powerful, it is the most frequently employed; and Gall openly denies, that we use both eyes at the same time, except in the passive exercise of the function. In active vision, he asserts, we always employ one eye only,—sometimes the one and sometimes the other; and thus, as we receive but one impression, we necessarily see but one object. In support of this view, he remarks, that, in many animals, the eyes are situated at the sides of the head, so as not to be capable of being directed together to the same object. In them, consequently, one eye can alone be used; and he considers this a presumption that such is the case in man. He remarks farther, that in many cases we use one eye by preference, in order, that we may see better; as in shooting, or in taking the direction of objects in a straight line, &c.; and that although, in other cases, both eyes may be open, we still use but one. In proof of this, he says the shade of a small object, placed between the eyes and a lighted body, does not fall between the eyes on the roof of the nose, as it ought to do if the body were regarded with both eyes, but on each eye alternately, according as the one or the other is directed to it; and, he adds, if when we squint voluntarily, we see two objects, it is because one eye sees passively, whilst the other is in activity.

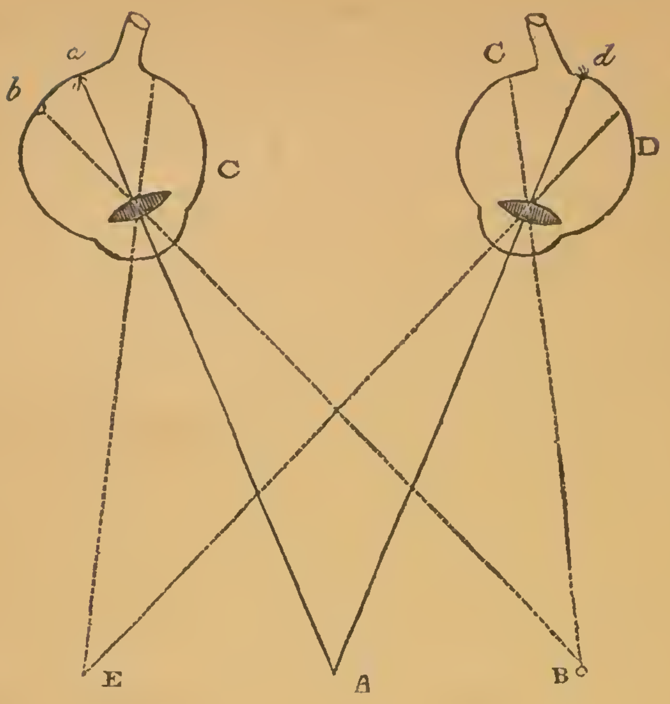
Amongst the numerous objections to this view of the subject, a few may be sufficient. Every one must have observed how much more vividly an object is seen with both eyes than with one only. The difference indeed according to Jurin is a constant quantity; and, in sound eyes of the ordinary degree of power, amounts to one-thirteenth of the whole effect. But we have experiment to show, that a distinct impression is made upon each eye.

If a solar beam be admitted into a dark chamber, and be made to pass through two glasses of tolerable thickness, but of different colours, placed close alongside each other, provided the sight be good, and the eyes of equal power, the light, which is perceived, will not be of the colour of either of the glasses, but will be of an intermediate shade; and, when this does not happen, it will be found that the eyes are of unequal power. When such is the case, the light will be of the colour of the glass, that is placed before the stronger eye. These results were obtained in the *Cabinet de Physique* of the *Faculté de Médecine* of Paris, by M. Magendie, in the presence of M. Thillaye the younger.

The existence of this double impression is proved in another way. If we place any tall, slender object a few feet before us, and examine its relative situation, compared with a spot on a wall in the distance, we find, that if the spot be hidden by the stick, when both eyes are open, it will become visible to each eye, when used singly; and will be seen on the side of the stick corresponding to the eye that is employed.

All these facts signally demonstrate, that two impressions are really made in all cases,—one on each eye;—and yet the brain has perception of but one. How the cerebral part of this function is executed we have not the slightest knowledge. All our information is limited to the fact, that, in the two eyes, there are *corresponding points*, on which if a similar impression be made, vision is single; but if the harmony in the movements of the eyes be in any manner disturbed, so that the rays proceeding from an object do not impinge upon corresponding points of the two retinæ, vision is double. This is merely stating the physical circumstances, necessary for single vision; and farther we cannot proceed, without entering the regions of conjecture.

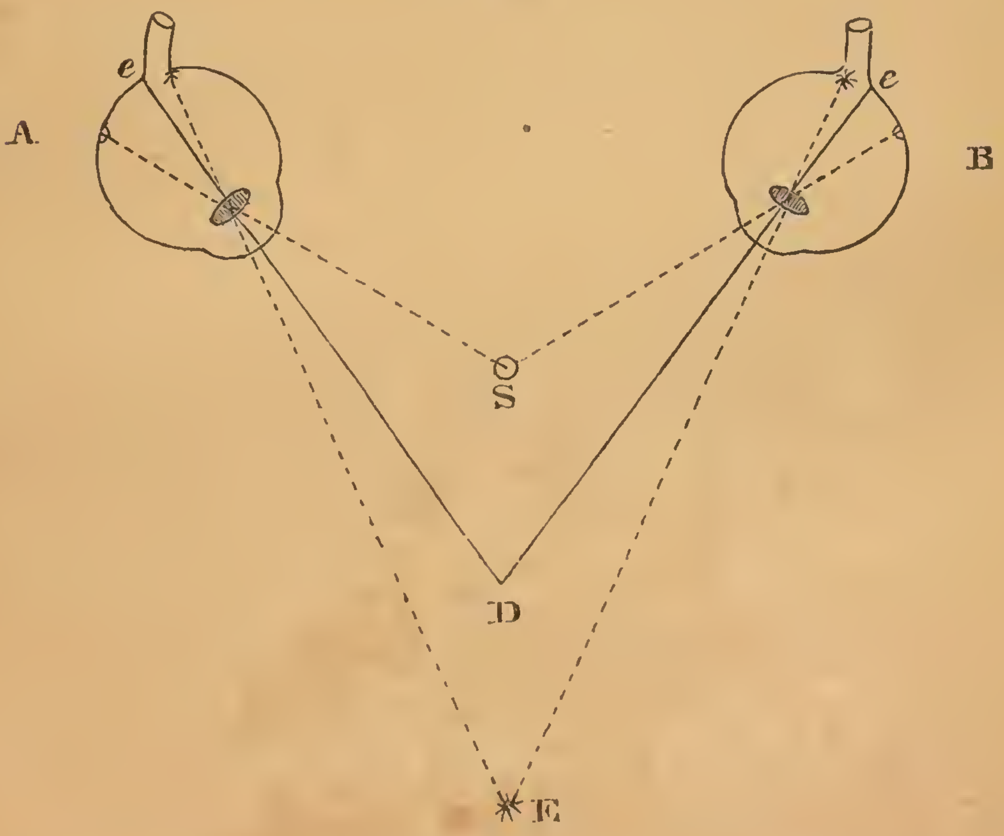
Fig. 41.



In Fig. 41, the star at A is seen exactly in the axes of the eyes at *a* and *d;* and it is seen singly, because the rays from it impinge upon the retina opposite the pupil in both eyes. These two are, therefore, corresponding points—instinctively or by habit; probably the former; and we have already seen, that vision is most distinct where the rays fall upon the centres of the retinæ; and that these centres have been called the *points of distinct vision.* Now, the other corresponding points of the retinæ are not, as Dr. Arnott has asserted, equidistant, and in similar directions from the centres of the retinæ. They are in similar directions, but not equidistant, as will be obvious from the figure. Let us suppose the axes directed to the star A, and that rays, from an object at B, strike the two eyes. This object, seen by oblique vision, will, for reasons previously stated, not be as distinct as the star A; but we know from experience, that it will be seen single. Experience, therefore, teaches us, that the points of the two retinæ, on which the rays from B impinge, are corresponding points. As, however, the rays from B fall on the two eyes with different obliquity, these points cannot be equidistant from the axes; the point c in the eye D being necessarily more remote. In all cases, however, of oblique vision, it is obvious, that in one eye the point will fall on the inner or nasal side of the axis; in the other, on the outer or temporal side. This seems essential; for if we so modify the experiment, that the rays from an object impinge upon the retina, with a different relation to the axes, the object is seen double; or, in other words, the rays do not fall upon *corresponding points.* Let us suppose the lines D *c* Fig. 42, to be the optic axes of the eyeballs A and B respectively; the object at D will, of course, be seen single; but a nearer object at S would be seen double; because all the rays, proceeding from it and passing through the optic centre of the crystalline in each eye, impinge upon the retinæ on the outer side of the axes; and are, therefore, not on corresponding points. In like manner, the rays, from a more distant object, at E, will impinge on the inner side of the axes, and double vision will be the consequence. That such is the case is easily proved, by holding the finger before the eye, and looking at any object a few feet distant: the finger will appear double; and if we shift our vision to the finger, the object will appear double.

In the course of the preceding remarks, it was said, that the eyes are not always of the same power. The difference is, indeed, sometimes surprising. M. Adelon mentions the case of a person, one of whose eyes required a *convex* glass, with a focus of five inches; the other, a *concave* glass with a focus of four inches. In these cases, it is important to use one unassisted eye only; as confusion must necessarily arise from directing both to an object. This is the cause why we close one eye in looking through a telescope. The instrument has the effect of rendering the focal distance of the two eyes unequal, and of placing them in the same situation as if they were, originally, of different powers.

Fig. 42.



If, from any cause, as from a tumour pressing upon one eyeball, from a morbid debility of the muscles, or from a want of correspondence in the sensibility of the two retinæ, the eyes are not properly directed to an object, double vision is the consequence; because the rays of light no longer fall upon corresponding points of the retinæ. In almost all cases, however, of distortion of the eyeballs, the image will fall upon a part of one retina, which is more sensible than the portion of the other on which it impinges; the consequence will be, that the mind will acquire the habit of attending to the impression on one eye only; and the other will be so neglected, that it will assume a position to interfere as little as possible with the vision of its fellow—so that, although at first, in *squinting*, there may be a double impression, vision is ultimately single. Buffon, who was of this opinion, affirms, that he examined the eyes of many squinters, and found that they were of unequal power; the weaker, in all cases, having turned away from its direction, and generally towards the nose, in order that fewer rays might reach it, and consequently vision be less interfered with. Yet, it is always found, if the sound eye be closed, that the other resumes its proper direction; a fact, which disproves the idea of De La Hire and others, that the cause of *strabismus* or *squinting* is a difference of sensibility in the corresponding points of the retinæ, and that the discordance in the movements of the organs occurs, in order that the images may still fall upon points of the retinæ, that are equally sensible. According to this view, both eyes must of course act.

The fact of the diverted eye resuming its proper direction, when the sound one is closed, is of important practical application. Many of the cases of squinting, which occur in infancy, have been induced by irregular action in the muscles of the eyeball; so that some having been, from accident or from imitation, used more frequently than others, the due equilibrium has not been maintained; double vision has resulted; and the affected eye has gradually attained its full obliquity. In these cases, we can, at times, remedy the defect, by placing a bright or conspicuous object in such a position as to exercise the enfeebled muscles; or, we can compel the whole labour of vision to be effected by one eye, and *that* the affected organ, which, under the stimulus, will be correctly exerted, and thus, by perseverance, the inequality may often be obviated. These indeed are the only cases in which we can expect to afford relief; for if the defect be in the interior of the eye, in a radical want of correspondence between the retinæ, or in inequality of the foci, it is irremediable.

It would appear, then, that, in confirmed squinting, one eye only is used, and that vision is single,—that the inclination of one eye inwards may be so great as to deprive it of function, or so slight as to allow the organ to receive rays from the same object as its fellow; but, in either case, it would seem, that they, who squint habitually, neglect the impressions on the distorted eye, and see with but one.

We have said, that the eyeball of the imperfect eye is drawn towards the nose, in order that as few rays as possible may penetrate the organ; and the vision of the sound eye be less liable to confusion. Sir Everard Home, however, conceives, that it takes this direction in consequence of the adductor muscle being stronger, shorter, and its course more in a straight line than that of any of the other muscles of the eye; and Sir Charles Bell ingeniously applies his classification of the muscles of the eye to an explanation of the same fact. He asserts, that the *recti* muscles of the eyeball are in activity during attention to the impression on the retina,—but that, when the attention is withdrawn, the straight muscles are relieved, and the eyeball is given up to the influence of the oblique muscles, the state of equilibrium between which exists, when the eyeball is turned, and the pupil presented upwards and inwards.

Lastly, in persons who are in the habit of taking repeated celestial observations, or in those who make much use of the microscope, the attention is so entirely directed to one eye, that the other is neglected, and, in time, wanders about, so as to produce squinting at the pleasure of the individual. In these cases, the eyes become of unequal power, so that one only can be employed where distinct vision is required.

So far our remarks have been directed to double vision, where both eyes are employed.

We have now to mention a very singular fact, connected with double and multiple vision with one eye only. If a hair, a needle, or any small object be held before one eye—the other being closed—and within the point of distinct vision, so that the bright light of a lamp or from a window shall fall upon the object, in its passage to the eye, or be reflected from it, we appear to see not one object but many.

This fact, when it was first observed by the author, appeared to him to have entirely escaped the observation of opticians and physiologists, inasmuch as it has not been noticed in any of the works recently published on optics or physiology. On reference, however, to the excellent "system," of Smith, on the former subject, he found in the "*Essay upon distinct and indistinct Vision*," by Dr. Jurin, appended to that work, the whole phenomenon explained, and elucidated at considerable length. The elaborate character of the explanation is probably the cause, why the fact has not been noticed by subsequent writers.

The best way of trying the experiment is that suggested by Jurin. Take a parallel ruler, and opening it slightly, hold it directly before the eye, so as to look at a window or lamp through the aperture. If the ruler be held at the visual point, the aperture will appear to form one luminous line; but if it be brought nearer to the eye, it will appear double, or as two luminous lines, with a dark line between them; and according as the aperture is varied,—or the distance from the eye,—two, three, four, five or more luminous and dark parallel lines will be perceptible.

At first sight, it might seem, that this phenomenon should be referred to the diffraction or inflection, which the light experiences in passing by the edges of the small body,—as the hair or needle. Newton had long ago shown, that, when a beam of light shines upon a hair, the hair will cast several distinct shadows upon a screen, and will, of course, present several images to the eye. Dr. Rittenhouse, in the second volume of the *American Philosophical Transactions*, explains, on the same principle, a very curious optical appearance, noticed by Mr. Hopkinson, in which, by the inflection of light, caused by the threads of a silk handkerchief, a multiple image of a distant lamp was presented.

The objections, however, to the explanation by inflection are,—that the image always appears single, if the object be not *within* the distance of distinct vision; and, secondly, the same multiple image is presented, when the object is seen by reflection, as when we look at a fine line, drawn upon paper; or at a fine needle held in a bright light. In this case, a considerable number of parallel images of the needle may be seen, all equally or nearly equally distinct, and not coloured.

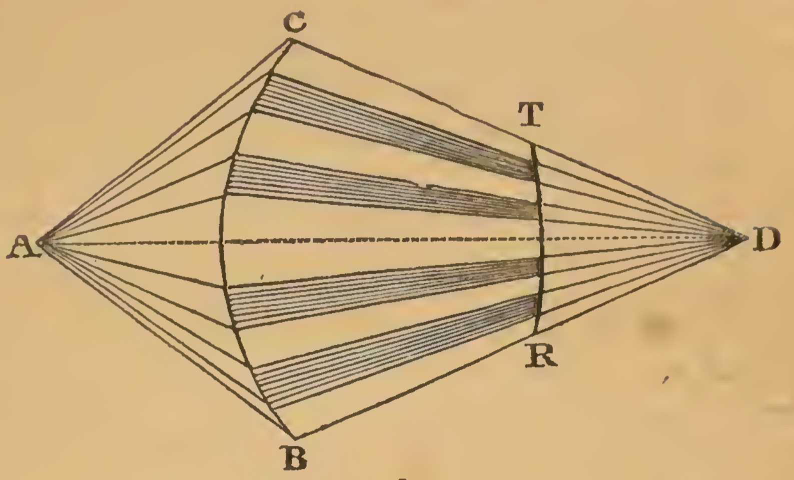
Dr. Jurin considers the phenomena to be caused by fits of easy refraction and reflection of light. Newton demonstrated, that the rays of light are not, in all parts of their progress, in the same disposition to be transmitted from one transparent medium into another; and that, sometimes, a ray, which is transmitted through the surface of the second medium, would be reflected back from that surface, if the ray had a little farther to go before it impinged upon it. This change of disposition in the rays,—to be either transmitted by refraction, or to be reflected by the surface of a transparent medium,—he called their *fits of easy refraction*, and *fits of easy reflection;* and he showed, that these fits succeed each other alternately at very small intervals in the progress of the rays.

Newton does not attempt to explain the origin of these fits, or the cause that produces them; but it has been suggested, that a tolerable idea of them may be formed by supposing, that each particle of light, after its emanation from a luminous body, revolves round an axis perpendicular to the direction of its motion, and presents alternately to the line of its motion an attractive and a repulsive pole, in virtue of which it will be refracted, if the attractive pole be nearest any refracting surface on which it falls, and reflected, if the repulsive pole be nearest the surface.

A less scientific notion of the hypothesis has also been suggested,—by supposing a body with a sharp and a blunt end passing through space, and successively presenting its sharp and blunt ends to the line of its motion. When the sharp end encounters any soft body it penetrates it: but when the blunt end encounters the same body, it will be reflected or driven back.

In applying this to the phenomenon in question, Jurin presumes,

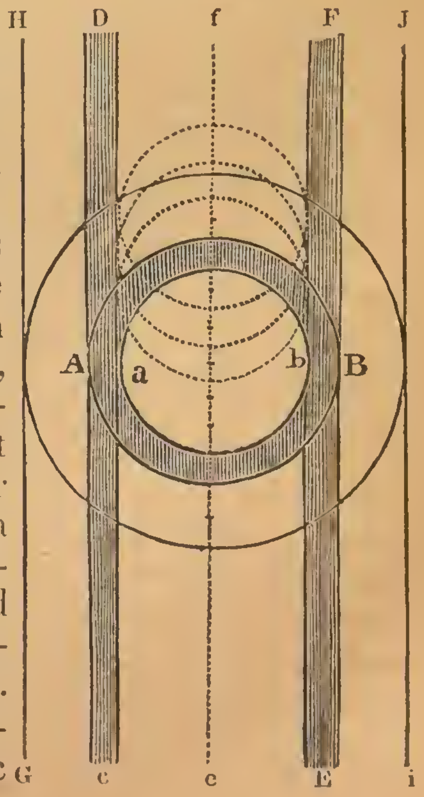
Fig. 43.



that the light, in passing through the humours of the eye, experiences these fits of easy refraction and easy reflection. This will be understood by the marginal figure, Fig. 43. From the point A, suppose a number of rays of light to proceed and to impinge, with different degrees of obliquity, on the denser medium, B C; all the rays, which are in fits of easy refraction, will pass through the medium to the point D; whilst those, that are in fits of easy reflection, will be thrown back into the medium A B C; so that we may presume, that all the rays, which fall upon the parts of the medium B C, corresponding to the bases of the dark cones will be reflected back, whilst those, that correspond to the bases of the light cones, will pass to a focus at D. Now, if all the bundles of rays, transmitted through the surface B C, be accurately collected into a focus, no other consequence will arise from the other bundles of rays having been reflected back, than that the focus will be less luminous, than it would have been had all the rays been transmitted through it.

This explains why, at the distance of distinct vision, we have only a single impression made on the eye.

Fig. 44.



But if we approach the object A, so that the focus is not thrown,—say upon the screen R T, which may be presumed to represent the retina—but behind it; the dark and light spaces will be represented upon the screen, and, of course, in concentric circles. This happens to the eye, when the hair or needle or other object, is brought nearer to it than the visual point. We can thus understand, why concentric circles, of the nature mentioned, should be formed upon the retina; but how is it, that the objects seen preserve their linear form? Suppose a b, Fig. 44, to be a luminous cone, which in a fit of easy refraction, has impinged upon the retina: and A B, b a, the concentric circles, corresponding to the rays, that have been reflected. It is obvious that every point of the object will be the centre of so many concentric circles on the retina; and if we imagine the fits of easy reflection and refraction to be the same around those points, we shall have the dark and lucid lines represented by the tangents to these circles; and hence we can comprehend why, instead of having one lucid line e f, we have three, separated by dark lines parallel to them; and if the light from the luminous point be strong enough to form more lucid rings than are represented in Fig. 44, and the breadth of those rings be not too minute to be perceived, we may have the appearance of five, seven, or more lucid lines, separated by parallel dark lines.

We proceed now to consider the advantages, which the mind derives from the possession of this sense, so pre-eminently entitled to the epithet *intellectual.*

Its immediate function is to give us the sensation of light and colour. In this it cannot be supplied by any of the other senses. The action is, therefore, the result of organization; or is a "law of the constitution;" requires no education; but is exercised as soon as the organ has acquired the proper developement. Yet, occasionally, we meet with singular cases, in which the eye appears to be totally insensible to certain colours, although capable of performing the most delicate functions of vision.

Sir David Brewster,—in his recent Treatise on Optics, in his Letters on Natural Magic, and in the article on *Optics* in the Library of Useful Knowledge, which is evidently an emanation from the same mind,—has collected several of these cases from various sources.

A shoemaker, of the name of Harris, at Allonby, in Cumberland, could only distinguish *black* and *white;* and, whilst a child, could not discriminate the cherries on a tree from the leaves, except by their shape and size. Two of his brothers were almost equally defective. One of them constantly mistook *orange* for *grass green*, and *light green* for *yellow.*

A Mr. Scott, who describes his own case in the *Philosophical Transactions*, for 1778, mistook *pink* for a *pale blue*, and a full *red* for a full *green.* His father, his maternal uncle, one of his sisters, and her two sons, had all the same defect.

A Mr. R. Tucker, son of Dr. Tucker, of Ashburton, mistakes orange for green, like one of the Harrises; and cannot distinguish blue from pink, but almost always knows yellow. He mistakes *red* for *brown*, *orange* for *green*, and *indigo* and *violet* for *purple.*

A tailor at Plymouth, whose case is described in the *Transactions of the Royal Society of Edinburgh*, by Mr. Harvey, of Plymouth, regarded the solar spectrum as consisting only of *yellow* and *light blue*; and he could distinguish, with certainty, only *yellow*, *white* and *gray.* He regarded *indigo* and *Prussian blue* as *black*, and *purple* as a modification of *blue.* *Green* puzzled him exceedingly; the darker kinds appearing to him *brown*, and the lighter kinds a pale *orange.*

On one occasion he repaired an article of dress with *crimson* instead of *black* silk; and, on another occasion, patched the elbow of a *blue* coat with a piece of *crimson* cloth.

A still more striking case is given by Dr. Nicol, in the *Medico-Chirurgical Transactions* of London, of a person in the British navy, who purchased a blue uniform coat and waistcoat, with red breeches to match.

Sir David Brewster refers to a case, that fell under his own observation, where the gentleman saw only the *yellow* and the *blue* colours of the spectrum.

This defect was experienced by Mr. Dugald Stewart, who was unable to perceive any difference between the colour of the scarlet fruit of the Siberian crab and that of its leaves.

Mr. Dalton, the chemist and philosopher, cannot distinguish *blue* from *pink* by daylight; and, in the solar spectrum, the *red* is scarcely visible; the rest of it appearing to consist of two colours, *yellow* and *blue*. Mr. Troughton, the optician, is fully capable of appreciating only *blue* and *yellow*; and when he names colours, the terms *blue* and *yellow* correspond to the more or less refrangible rays;—all those, that belong to the former, exciting the sensation of blueness; and those, that belong to the latter, that of yellowness.

The opinions of philosophers have varied regarding the cause of this singular defect in eyes otherwise sound, and capable of performing every other function of vision in the most delicate and accurate manner.

By some, it has been presumed to arise from a deficiency in the visual organ; and by such as consider the ear to be defective in function, in those that are incapable of appreciating musical tones, this deficiency in the eye is conceived to be of an analogous nature. "In the sense of vision," says Dr. Brown, "there is a species of defect very analogous to the want of musical ear,—a defect, which consists in the difficulty, or rather the incapacity, of distinguishing some colours from each other—and colours, which, to general observers, seem of a very opposite kind. As the want of musical ear implies no general defect of mere quickness of hearing, this visual defect, in like manner, is to be found in persons who are yet capable of distinguishing, with perfect accuracy, the form, and the greater or less brilliancy of the coloured object; and I may remark, too, in confirmation of the opinion, that the want of musical tone depends on causes not mental but organic, that in this analogous case some attempts, not absolutely unsuccessful, have been made to explain the apparent confusion of colours by certain peculiarities of the external organ of sight."

Mr. Dalton, who believes the affection to be seated in the physical part of the organ, has endeavoured to explain his own case, by supposing that the vitreous humour is *blue*, and therefore absorbs a great portion of the red and other least refrangible rays; and Sir David Brewster, in the *Library of Useful Knowledge*, appears to think, that it may depend upon a want of sensibility in the retina, similar to that observed in the ears of those who are incapable of hearing notes above a certain pitch; but as this view is not contained in his more recent *Treatise on Optics*, it is probably no longer considered by him to be satisfactory.

The defect in question has always appeared to us entirely cerebral, and to strikingly resemble, as Dr. Brown has suggested, the "want of musical ear." As we have already endeavoured to establish, that the latter is dependent upon a defective mental appreciation, the parity of the two cases will, of course, compel us to refer the visual defect, or the want of the "faculty of colouring," to the same cause. It has been remarked, that the eye, in these cases, exercises its function perfectly, as regards the form and position of objects, and the degree of illumination of their different portions. The only defect is in the imperfect conception of colour. The nerve of sight is probably accurately impressed, and the deficiency is in the part of the brain, whither the impression is conveyed, and where perception is effected, which is incapable of accurately appreciating those differences between rays, on which their colour rests; and this we are glad to find is the view taken of it by one of the most eminent philosophers of the present day, Sir J. F. W. Herschel.

The *mediate* or *auxiliary* functions of vision are numerous; and hence, the elevated rank that has been assigned to this sense. By it, we are capable of judging, to a certain extent, of the direction, position, magnitude, distance, surface, and motion of bodies. Metaphysicians have differed greatly in their views on this subject; the majority believing, that, without the sense of touch, the eye is incapable of forming any accurate judgment on these points; others, that the sense of touch is no farther necessary than as an auxiliary; and that a correct appreciation could be formed by sight alone. The few remarks, that may be necessary on this subject, will be deferred, until the physical and other circumstances, which enable us to judge of distance, &c., have been canvassed.

The *direction* or *position* of objects has already been considered, so far as regards the inverted image, formed by them on the retina. The errors, that arise on this point, are by no means numerous, and seldom give rise to much inconvenience. The direction of the light, that impinges on the retina, is always referred, as we have attempted to demonstrate, in the direction of a line, drawn from the luminous point through the optic centre of the crystalline. Whenever, therefore, the luminous cone meets with reflection or refraction, before reaching the eye, the retina conveys erroneous information to the sensorium, and we experience an *optical illusion*.

To ascertain the *magnitude*, *distance*, and *surface* of bodies, we are obliged to take into consideration several circumstances connected with the appearance of the object—such as its apparent size, the intensity of light, shade and colour, the convergence of the axes of the eyes, the size or position of intervening objects, &c.

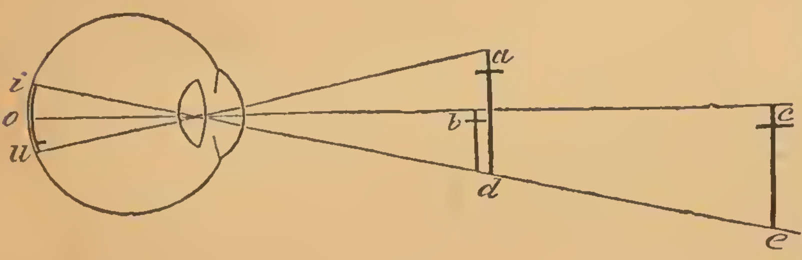
Porterfield enumerates six methods, which are employed in appreciating the distance of objects—1, their apparent magnitude; 2, the vivacity of their colours; 3, the distinction of their smaller parts; 4, the necessary conformation of the eye for seeing distinctly at different distances; 5, the direction of their axes; and 6, the interposition of objects.

Dr. Brown reduces them to three—1, the difference of the affections of the optic nerve; 2, the different affections of the muscles, employed in varying the refracting power of each eye, according to the distance of objects, and in producing that particular inclination of the axes of the two eyes, which directs them both equally on the particular object; and 3, the previous knowledge of the distance of other objects, "which form with that we are considering a part of one compound perception."

Lastly, Dr. Arnott, in his "*Elements of Physics*," enumerates four modes by which this is effected—1. The space and place, occupied by objects in the field of view, measured by what is termed the *visual angle*. 2. The intensity of light, shade, and colour. 3. The divergence of the rays of light—and 4. The convergence of the axes of the eyes. This enumeration may be adopted, with some slight modifications. The circumstances, in our opinion to be considered, are:—

1. The *visual angle*, or that formed by two lines, which shave the extremities of an object, and cross at the centre of the crystalline; so that the *visual angle*, subtended by the object, as *a d*, Fig. 45, is exactly equal to that subtended by its image *i u* on the retina. It is obvious, from this figure, that if all objects were equidistant from the eye, and of the same magnitude, they would subtend the same angle; and, if not of the same magnitude, the difference would be accurately indicated by the difference in the visual angle subtended by them; thus, the comparative size of the two crosses *a d* and *b d* is represented by that of the images *i u* and *i o*. The cross *c e*, however, which is twice the size of *b d*, subtends the same visual angle, and is alike represented on the retina by the image *i o*. It is clear, then, that the visual angle does not, under such circumstances, give us a correct idea of the relative magnitudes of bodies, unless we are acquainted with their respective distances from the eye; and,

Fig. 45.

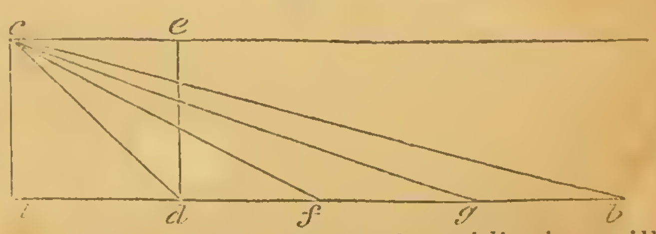


conversely, we cannot judge accurately of their distances, without being aware of their magnitudes.

A man on horseback, when near us, subtends a certain visual angle; but, as he recedes from us, the angle becomes less and less; yet we always judge accurately of his size, because aware of it by experience; but if objects are at a great distance, so as not to admit of their being compared with nearer objects by simple vision, we are in a constant state of illusion—irresistibly believing, that they are much smaller than they really are. This is the case with the heavenly bodies. The head of a pin held close to the eye will subtend as large a visual angle as the planet Jupiter, which is one thousand two hundred and eighty-one times bigger than this earth, and is eighty-six thousand miles in diameter. In like manner, a five-cent piece, held at some distance from the eye, will shut off the sun, although its diameter is eight hundred and eighty-eight thousand miles. The sun and moon, again, by subtending nearly the same visual angle, appear to us of nearly the same size; and the illusion persists in spite of our being aware of the mathematical accuracy, with which it has been determined, that the former is ninety-six millions of miles from us, and the latter only two hundred and forty thousand.

The visual angle, again, subtended by an object, differs greatly according to the position of the object. A sphere has the same appearance or bulk, when held at a certain distance from the eye, whatever may be the position in which it is viewed; and, accordingly, the visual angle, subtended by it, is always identical. Not so, however, with an oval. If held, so that the rays from one of its ends shall impress the eye, it will occasion a circular image, and subtend a much smaller angle, than if viewed sideways, when the image will be elliptical, or oval. The same thing must occur with every object, whose longitudinal and transverse diameters differ. It is obvious, that if any such object be held in a sloping position towards the eye, it will appear more or less shortened; precisely in the same manner as the slope of a mountain or inclined plane would appear much greater, if placed perpendicularly before the eye. This appearance is what is called *foreshortening;* and it may be elucidated by the following figure. Suppose a man to be standing on a level plain, with his eye at *c*, looking down on the plain. The portion of the surface *a d*, which is next to him, will be seen without any foreshortening; but if we suppose him to regard successively the portions *d f*, *f g*, and *g b* of the plain, the angle, subtended by each portion, will diminish; so that if the angle *a c d* be 45°, *d c f* will be 18°; *f c g* 8°, and so on; until, at length, the obliquity will

Fig. 46.

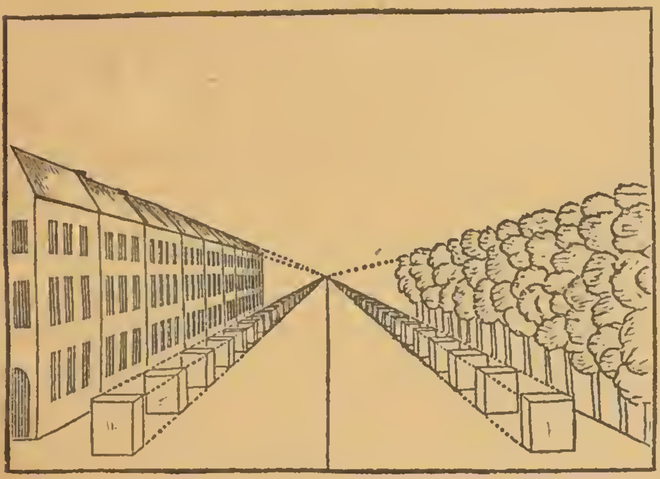


be so great, that the angle becomes inappreciable. This is the cause why, if we look obliquely upon a long avenue of trees, we are unable to see the intervals between the farthest in the series; although that between the nearest to us may be readily distinguished.

In all paintings, of animals especially, the principle of foreshortening has to be rigidly attended to: and it is owing to a neglect of this, that we see such numerous distorted representations—of the human figure particularly.

It has been already stated, that objects appear smaller according to their distance; hence, the houses of a street, or the trees of an avenue, that are nearest to us, or in the foreground, will form the largest images on the retina, and there will be a gradual diminution, so that, if we could imagine lines to be drawn along the tops and bottoms of the objects, and to be sufficiently prolonged, they would appear to meet in a point, as in Fig. 47. The art which traces objects, with their various degrees of apparent diminution on account of distance, and of foreshortening on account of obliquity of position, is called *perspective*.

Fig. 47.



2. *The intensity of light, shade, and colour.*—It has been shown, that the intensity of light diminishes rapidly, according to the distance of the body, from which it emanates; so that it is only one-fourth as powerful when doubly distant, one sixteenth when quadruply distant, and so on. This fact is early recognized; and the mind avails itself of it to judge, with much accuracy, of relative distances. It is, however, a pregnant source of optical illusions. In a bright sunshine, the mountains appear much nearer to us than when seen through the haze of our *Indian summer.**

In a row of lamps along a street, if one be more luminous than the rest, it will seem to be the nearest; and, in the night, we incur the strangest errors, in judging of the distance of any luminous body.

* A delightful season in the southern and western parts of North America, generally happening in October or November; and having nothing similar to it, so far as we are aware, in any other part of the globe. It is dependent upon some meteorological condition of the atmosphere, and occurs only when the wind is southerly, or from the warmer regions; disappearing immediately as soon as it veers to the north. By some, this phenomenon has been supposed to be caused by the large fires in the western prairies; but the warmth that attends the haze cannot be explained on this hypothesis, independently of other sufficient objections to it.

The sky appears nearer to the earth directly above, than it does towards the horizon; because the light from above having to pass only through the atmosphere, is but slightly obstructed, whilst a portion only of that, which has to pass through the dense heterogeneous air, near the surface of the earth, arrives at the eye. The upper part of the sky being, therefore, more luminous, seems nearer; and, in the same manner, we explain, in part, why the sun and moon appear larger at rising and setting.

The shade of bodies keeps pace with their intensity of light; and, accordingly, the shadows of objects near us, are strongly defined;—whilst in the distance they become confused, and the light altogether so faint, that the eye at last sees an extent of distant blue mountain or plain; "appearing bluish," says Dr. Arnott, "because the transparent air, through which the light must pass, has a blue tinge, and because the quantity of light arriving through the great extent of air is insufficient to exhibit the detail." "The ridge called Blue Mountains," he adds, "in Australia, and another of the same name in America, and many others elsewhere, are not really blue, for they possess all the diversity of scenery, which the finest climates can give; but to the discoverer's eye, bent on them from a distance, they all at first appeared blue, and they have ever since retained the name."

As regards the *Blue Ridge* of America, Dr. Arnott probably labours under misapprehension. Within a very few miles from the whole of this extensive chain, as well as from a distance, the blue tinge is perceptible, especially when the air is dense and clear, soon after the sun has descended behind it; so that the name is as appropriate in the vicinity as it was when "the discoverer's eye was bent on it from a distance."

It is obvious, that without the alternation of light and shade we should be unable to judge, by the eye, of the shape of bodies; to distinguish a flat circle from a globe; or any of the prominences and depressions, that are every where observable. The universe would appear a flat surface, the outlines of which would not even be perceptible; and the only means of discriminating objects would be by their difference of colour.

It is partly by attending to the varying intensity of light and shade, that the painter succeeds in representing the near as well as the distant objects in an extensive landscape: those in the foreground are made bold and distinct; whilst the remote prospect is made to become gradually less and less distinct, until it fades away in the distance. This part of his art is called *aerial perspective.*

3. *Convergence of the axes.* When objects are situated at a moderate distance from us, we so direct the eyes, that if the axes were prolonged they would meet at the object, as at D. Fig. 42. This angle will, of course, vary inversely as the distance; so that if the axes be turned to the object S, the angle will be greater; if to E, less. By this change in the direction of the axes the mind is capable

of judging, to a certain extent, of near distances. A definite muscular effort is required for each particular case; and the difference in the volition necessary to effect it enables the brain to discriminate, precisely in the same manner as it judges of the height of a body, by the muscular action, required to carry the axis from one extremity of the object to the other.

We have the most satisfactory evidence, that such convergence of the axes is indispensable for judging accurately of distance, in near vision. If we fix a ring to a thread suspended from a beam, or attach it to a stand, and endeavour, with one eye closed, to pass a hook, fixed to the extremity of a rod four or five feet long, into the ring, we shall find it impracticable unless by accident or by touching the ring with the rod. The hook will always be passed on the far or near side of the ring; but if we use both eyes, we can readily succeed. They, however, whose eyes are of unequal power, cannot succeed with both eyes.

The fact is strikingly corroborated by the difficulty experienced by those who have lost an eye. Magendie says it sometimes takes a year, before they can form an accurate judgment of the distance of objects placed near the eye. The truth is, however, as we have known in one or two interesting examples, that the power is occasionally never regained; notwithstanding every endeavour to train the remaining organ.

It need scarcely be said, that the convergence of the axes is no guide to us in estimating objects, which are at such a distance, that the axes are nearly parallel; as the sun and moon, or any of the celestial luminaries.

4. The *interposition of known objects.* Another mode of estimating the magnitude or distance of objects is, by a previous knowledge of the magnitude or distance of interposed or neighbouring objects; and if no such objects intervene, the judgment we form is extremely inaccurate. This is the reason, why we are so deceived in the extent of an unvaried plain or in the distance at which a ship, on the ocean, may be from us: it is also another cause, why the sky appears to us to be nearer at the zenith than it is at the horizon.

The artist avails himself of this means of judging of magnitude in his representations of colossal species of the animal or vegetable kingdom; or of the works of human labour and ingenuity; by placing a well known object alongside of them as a standard of comparison. Thus, the representation of an elephant or a giraffe might convey but imperfect notions to the mind, without that of his keeper being added as a corrective.

It is in consequence of the interposition of numerous objects, that we are able to judge more accurately of the size and distance of objects that are on the same level with us, than when they are either much above or much below us.

The size and distance of a man on horseback are easily recognized by the methods already mentioned, when he is riding before us on a dreary plain; the man and the horse appearing more diminutive, but, being seen in their usual position, they serve as mutual sources of comparison. When, however, the same individual is viewed from an elevated height, his apparent magnitude, like that of the objects around him, is strikingly less than the reality. How beautifully and accurately this effect is depicted by the great dramatist: —

"How fearful
And dizzy 'tis to cast one's eyes so low!
The crows and choughs, that wing the midway air,
Show scarce so gross as beetles. Half way down
Hangs one that gathers samphire; dreadful trade!
Methinks he seems no bigger than his head.
The fishermen, that walk upon the beach,
Appear like mice: and yon tall anchoring bark,
Diminish'd to her cock; her cock a buoy
Almost too small for sight."

The apparent diminution in the size of objects seen from a height is not to be wholly explained by the foreshortening, which deprives us of our usual methods of judging. It is partly owing to the absence of intervening bodies; and still more perhaps to our not being accustomed to view objects so circumstanced.

Similar remarks apply to our estimates of the size and distance of objects placed considerably above us. A cross, at the summit of a lofty steeple, will not appear more than one-fourth of its real size, making allowance for the probable distance; yet a singular anomaly occurs here:—the steeple itself seems taller than it really is, and every one supposes, that it would extend much farther along the ground, if prostrated, than it would in reality. The truth, however, is, that if the steeple were laid along the ground, unsurrounded by objects to enable us to form an accurate judgment, it would appear to be much shorter than when erect, on the principles of foreshortening, already explained. The cause of this small apparent magnitude of the cross and upper part of the steeple is, that they are viewed without any surrounding objects to compare with them: they, therefore, seem to be smaller than they are; and, being smaller, the mind irresistibly refers them to a greater distance. For these reasons, then, it becomes necessary, that figures, placed on lofty columns, should be of colossal magnitude.

It is owing partly to the intervention of bodies, that the sun and moon appear to us of greater dimensions, when rising or setting, although the visual angle, subtended by them, may be the same.

"The sun and moon," says Arnott, "in appearance from this earth are nearly of the same size, viz:—always occupying in the field of view about the half of a degree, or as much as is occupied by a circle of a foot in diameter, when held about two hundred and fifty feet from the eye—which circle, therefore, at that distance, and at any time, would just hide either of them. Now, when a man sees the rising moon apparently filling up the end of a street, which he knows to be one hundred feet wide, he very naturally believes, that she then subtends a greater angle than usual, until the reflection occur to him—which it rarely will of itself, that he is using, as a measure of her size, a street known, indeed to be one hundred feet wide, but of which the part concerned, owing to its distance, appears to his eye exceedingly small. The width of the street near him may occupy sixty degrees in his field of view, and he might see from between the houses many broad constellations instead of the moon only; but the width of the street far off may not occupy, in the same field of view, the twentieth part of a degree, and the moon, which always occupies half a degree, will then appear comparatively large. The kind of illusion, now spoken of, is yet more remarkable, when the moon is seen rising near still larger known objects,—for instance, beyond a town or a hill which then appears within her luminous circle."

Such are the chief methods by which we form our judgment of the distance and magnitude of bodies;—1st, by the visual angle—2dly, by the intensity of light, shade, and colour—3dly, by the convergence of the axes of the eyes—and 4thly, by the interposition of known objects.

The eye also enables us to appreciate the *motion* of bodies. This it does by the movement of their images upon the retina; by the variation in the size of the image; and by the altered direction of the light in reaching the eye.

If a body be projected with great force and rapidity, we are incapable of perceiving it;—as in the case of a shot fired from a gun, especially when near us. But if it be projected from a distance, as the field of view is very extensive, it is more easy to perceive it. The bombs, sent from an enemy's encampment, can be seen far in the air for some time before they fall, in the darkness of night; and afford objects for interesting speculation regarding their probable destination.

To form an accurate estimation of the motion of a body, we must be ourselves still. When sailing on a river, the objects, that are stationary on the banks, appear to be moving, whilst the boat, which is in motion, seems to be at rest.

Bodies, that are moving in a straight line to or from us, scarcely appear to be in motion. In such cases, the only mode we have of detecting their motion is by the gradual increase in their size and illumination, when they approach us; and the converse, when they are receding from us.

If at a distance, and the visual angle between the extreme points of observation be very small, the motion of an object will likewise appear extremely slow; hence the difference between a carriage dashing past us in the street, and the same object viewed from a lofty column. A balloon may be moving along at the rate of nearly one hundred miles per hour; yet, except for its gradual diminution in size and in intensity of light, it may appear to be at rest; and, when bodies are extremely remote from us, however astonishing may be their velocity, it can scarcely be detected. Thus, the moon revolves round the earth at the rate of between thirty and forty miles a minute—above forty times swifter than the fleetest horse; yet her motion, during any one moment, completely escapes detection; and the remark applies still more forcibly to those luminaries, which are at a yet greater distance from the earth.

These are cases in which the body moves with excessive velocity, yet the image on the eye is almost stationary; but there are others, in which the *real* motion is extremely slow, and cannot be at all observed, as that of the hour-hand of a clock or watch.

It will be obvious, from all the remarks that have been indulged, regarding the information derived by the mind from the sense of sight, that a strictly intellectual process has to be executed, without which no judgment can be formed; and that nothing can be more erroneous than the notion,—at one time prevalent,—that the method by which we judge of distance, figure, &c., is instinctive or dependent upon an original "law of the constitution," and totally independent of any knowledge gained through the medium of the external senses. It has already been remarked, that metaphysicians may be considered as divided into those, who believe that, without the sense of touch, the eye would be incapable of forming any accurate judgment on these points; and those, who think, that the sense of touch is no farther necessary than as an auxiliary, and that a correct appreciation can be formed by sight alone.—Molyneux, Berkeley, Condillac, &c. support the former view; Gall, Adelon, &c. the latter.

Of the precise condition of the visual perception, during early infancy, we are of course entirely ignorant. So far as our own recollections would carry us back, we have always been able to form a correct judgment of magnitude, distance, and figure. Observation, however, of the habitudes of infants would seem to show, that their appreciation of these points—especially of distance—is singularly imprecise, but whether this be owing to the sense not yet having received a sufficient degree of assistance from touch, or from want of the necessary developement in the structure or functions of the eyeball or its accessory parts, we are precluded from judging.

The only succedaneum is the information to be obtained, regarding their visual sensations, from those, who have been blind from birth, and have been restored to sight by a surgical operation.

Although in the numerous operations of this kind, which have been performed, it might seem, that cases must have frequently occurred for examining into this question, such is not the fact; and metaphysicians and physiologists have generally founded their observations on the celebrated case described by Cheselden in his *Anatomy*.

The subject of this was a young gentleman, who was born blind, or lost his sight so early, that he had no remembrance of ever having seen, and was "couched," so says Cheselden, "between thirteen and fourteen years of age." Magendie affirms, that there is every reason to believe, that the operation was not that for cataract, but consisted in the incision of the pupillary membrane. It need hardly be remarked, that Cheselden must be the best possible authority on this subject.

"When he first saw," says Cheselden, "he was so far from making any judgment about distances, that he thought all objects whatever touched his eyes, (as he expressed it,) as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object that was pleasing to him. He knew not the shape of anything, nor any one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe, that he might know them again; but having too many objects to learn at once, he forgot many of them; and, (as he said,) at first he learned to know, and again forgot a thousand things in a day. At first he could bear but very little light, and the things he saw he thought extremely large; but, upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw; the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger."

A much more interesting case, in many respects, than this of Cheselden's, which has always appeared to us too poetical, was laid before the Royal Society of London, in 1826, by Mr. Wardrop. It was that of a lady born blind, who received sight at the age of forty-six, by the formation of an artificial pupil. During the first months of her infancy, this lady was observed to have something peculiar in the appearance of her eyes; and, when about six months old, a Parisian oculist operated on both eyes, with the effect of complete destruction of the one, and not the slightest improvement to the other. From this time, she continued totally blind, being merely able to distinguish a very light from a very dark room, but without the power of perceiving even the situation of the window through which the light entered, though, in sunshine or bright moonlight, she knew its direction; she was, therefore, in greater darkness than the boy in Cheselden's case, who knew black, white, and scarlet, apart from each other; and, when in a good light, had that degree of sight, which usually exists in an eye affected with cataract; whilst in this lady, the pupil was completely shut up, so that no light could reach the retina, except such rays as could pass through the substance of the iris.

After a third operation had been performed, for the formation of an artificial pupil, she returned from Mr. Wardrop's house in a carriage, with her eye covered with only a loose piece of silk. The first thing she noticed was a hackney-coach passing by, when she exclaimed, "What is that large thing that has passed by us?" In the course of the evening she requested her brother to show her his watch, and she looked at it a considerable time, holding it close to her eye. "She was asked what she saw, and she said there was a dark and a bright side; she pointed out to the hour of twelve and smiled. Her brother asked her if she saw anything more; she replied yes, and pointed to the hour of six, and to the hands of the watch. She then looked at the chain and seals, and observed that one of the seals was bright, which was the case, being a solid piece of rock crystal." On the third day she observed the doors on the opposite side of the street, and asked if they were red. They were of an oak colour. In the evening she looked at her brother's face, and said she saw his nose; he asked her to touch it, which she did; he then slipped a handkerchief over his face, and asked her to look again, when she playfully pulled it off, and asked, "What is that?" On the thirteenth day, she walked out with her brother in the streets of London, when she distinctly distinguished the street from the foot pavement, and stepped from one to the other, like a person accustomed to the use of her eyes." "Eighteen days after the last operation," says Mr. Wardrop, "I attempted to ascertain, by a few experiments, her precise notions of the colour, size and forms, position, motions and distances of external objects. As she could only see with one eye, nothing could be ascertained respecting the question of double vision. She evidently saw the difference of colours; that is, she received and was sensible of different impressions from different colours. When pieces of paper, one and a half inch square, differently coloured, were presented to her, she not only distinguished them at once from one another, but gave a decided preference to some colours, liking yellow most, and then pale pink. It may be here mentioned, that, when desirous of examining an object, she had considerable difficulty in directing her eye to it, and finding out its position, moving her hand as well as her eye in various directions, as a person, when blindfolded or in the dark, gropes with his hand for what he wishes to touch. She also distinguished a large from a small object, when they were both held up before her for comparison. She said she saw different forms in various objects, which were shown to her. On asking what she meant by different forms, such as long, round, and square, and desiring her to draw with her finger these forms on her other hand, and then presenting to her eye the respective forms, she pointed to them exactly; she not only distinguished small from large objects, but knew what was meant by above and below; to prove which, a figure drawn with ink was placed before her eye, having one end broad, and the other narrow, and she saw the positions as they really were, and not inverted.(!!) She could also perceive motions; for when a glass of water was placed on the table before her, on approaching her hand near it, it was moved quickly to a greater distance, upon which she immediately said, 'You move it; you take it away.' She seemed to have the greatest difficulty in finding out the distance of any object; for, when an object was held close to her eye, she would search for it by stretching her hand far beyond its position, while on other occasions she groped close to her own face for a thing far remote from her."

We have given the particulars of this case at some length, inasmuch as they are regarded by Dr. Bostock—and apparently by Mr. Wardrop himself—as strikingly confirmatory of those of Cheselden, than which we cannot imagine anything more dissimilar. It will have been noticed, that, from the very first after the reception of sight, she formed an imperfect judgment of objects, and even of distances, although she was devoid of the elements necessary for arriving at an accurate estimate of the latter—the sight of both eyes. This was, doubtless, the chief cause of that groping for objects, which is described by Wardrop. Of forms, too, she must have had at least an imperfect notion, for we find, that, on the 13th day after the operation, she stepped from the elevated foot-pavement to the street, "like a person accustomed to the use of her eyes."

The case is, we think, greatly in favour of the view, that the sight does not require much education to judge with tolerable accuracy of the position, magnitude, distance, surface, and motion of bodies; and that, by a combination of the methods we have already pointed out, or of some of them, this imperfect knowledge is obtained, without the aid of any of the other senses; but is of course acquired more easily and accurately with their assistance, especially with that of touch. What other than visual impressions could have communicated to the mind of Miss Biffin—whose case was referred to under another head—the accurate and minute information, which she possessed regarding the bodies surrounding her, at all distances? Or how does the animal, immediately after birth, acquire its knowledge of distance? We observe the young of many, immediately after they are extruded from the uterus, turn round and embrace the maternal teat; whilst others, as the partridge, follow the mother immediately after they have burst the shell.

The experience required for obtaining an imperfect knowledge of distance, shape, &c. must, therefore, be trifling; although an accurate acquaintance may demand numerous, and careful comparisons. This first degree of knowledge is probably obtained, by comparing the visual angle with the intensity of light, shade, and colour—the more accurate appreciation following the use of the other methods already described. That the convergence of the axes requires education is demonstrated in the case of the infant. It has been remarked, that the eyeballs harmonize instinctively in their parallel motions; but the convergence requires an effort of volition, and it is some time before it can be effected, which is probably the great cause of the mal-appreciation of near distances, which we notice in the infant; whilst it seems to exhibit its capability of judging more correctly of objects, that are somewhat more remote, and where less convergence, and, consequently, less muscular effort is necessary.

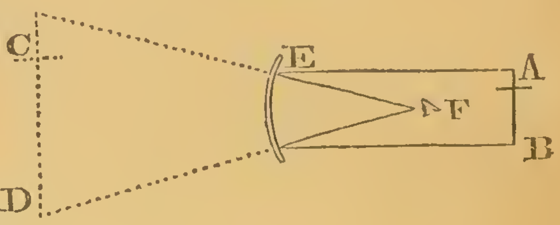
The numerous *optical illusions*, which, we have been compelled to describe, in the progress of the preceding remarks, will render it necessary to refer to but few under this head.

It has already been said, that we lay it down as a rule, that the progress of light to the eye is always in a straight line from the luminous object; and, accordingly, if the course of the rays be modified before they reach the organ, we fall into an optical illusion. Such modifications arise either from the reflection or refraction of the rays proceeding from the object that causes the sensation.

By reflection of the rays, we experience the illusion caused by mirrors. A ray of light, K C, Fig. 22, falling upon a plane mirror, I J, is reflected back in the same line; but, as we have seen, the object will not appear to be at K, but at E. Again, a ray of light, proceeding obliquely from B, and impinging on a plane mirror at C, will be reflected in the direction C A; but to an eye at A, the object B will appear to be at H, in the prolongation of the ray that reaches the eye.

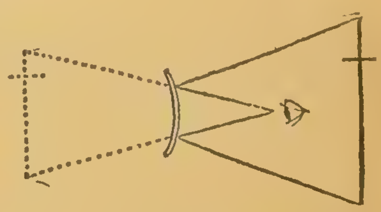
If the mirror be concave, the object will appear magnified, provided the light from the upper part of the object, as A B, Fig. 48, be reflected to an eye at F, and that from the lower part of the object meet the other at this point. To an eye so placed, the object will appear magnified, and seem to be at C D, or in the prolongation of the rays which fall upon the cornea.

Fig. 48.



If the mirror, as in Fig. 49, be convex, for like reasons, the cross will seem to be smaller. The cornea constitutes a mirror of this class, in which we have an accurate miniature representation of objects.

Fig. 49.



Rays, that are refracted in passing through different media, also give rise to visual illusions. We have seen, that the ray from an object at F, Fig. 22, in the pool of water, I J, does not proceed into the air in the direction F C O, but in that of the line F C A; and if we suppose the eye to be placed at A, the object will not be seen at F, but will appear to be at *f;* the pool will, consequently, appear shallower than it really is, by the space at which *f* is situated above the bottom.

We can now understand, why rivers should appear shallower than they really are, when viewed obliquely; and why the lower end of a pole, immersed in water, should, when seen obliquely, appear to be bent towards the surface. In shooting fish in the water, or in attempting to harpoon them, this source of error has to be corrected. Those birds, too, that live upon the inhabitants of the water, will have to learn, from experience, to obviate the optical illusion; or to descend perpendicularly upon their prey, in which direction, as we have seen, no refraction takes place. Similar remarks apply to the fish that leap out of the streams to catch objects in the air. The *Chætodon rostratus*, about six or eight inches long, frequents the sea-shores in the East Indies: when it observes a fly, sitting on the plants that grow in shallow water, it swims to the distance of five or six feet, and then, with surprising dexterity, ejects out of its tubular mouth a single drop of water, which never fails to strike the fly into the sea, where it soon becomes its prey. Hommel—a Dutch governor—put some of these fish into a tub of water, and then pinned a fly on a stick within their reach. He daily saw the fish shoot at the fly, and, with such dexterity, that they never failed to hit their mark. Pallas describes the *Siæna Jaculatrix* as securing flies by a similar contrivance.

If the light, before reaching the eye, passes through bodies of a lenticular shape, it undergoes modifications, which have given occasion to the formation of the useful instruments, that have been devised for modifying the sphere of vision. If the lens be double convex, the body, seen through it, appears larger than it is, from the illusion so often referred to, that we always refer the object in the direction of the line, that impinges upon the retina. The object, consequently, appears to be greatly augmented. (See Fig. 28.) For the same reasons an object seems smaller to an eye at A, Fig. 25, when viewed through a double concave lens.

Again, if the light, before reaching the cornea, is made to pass through a diaphanous body, which is itself coloured, and consequently allows only the rays of its own colour to traverse it, the object is not seen of its proper colour, but of that of the transparent body.

An impression of light continues to affect the retina for the sixth part (M. D'Arcy says the seventh part,) of a second. If, therefore, a live coal be whirled round in a circle, six or seven times in a second, it will seem to be a continuous circle of fire. It is owing to this circumstance, that meteors seem to form a line of light,—as in the case of the falling star,—and that the same impression is conveyed by a skyrocket in its course through the air. We have an elucidation of this fact in the instrument or toy—called, by Dr. Paris, the *thaumatrope*—which consists of a circle, cut out of a card, and having two silken strings attached to opposite points of its diameter:

by twisting these with the finger and thumb the card may be twirled round with considerable velocity. On one side of the card an object is drawn—such as a chariot—and on the other, the charioteer. If the card be twirled round six or seven times in a second the charioteer will be seen in the chariot; the duration of the impressions on the retina being such as to cause the figures, drawn on both sides of the card, to be seen at the same time.

Lastly,—it is by accurate attention to various optical illusions, and to the laws of the animal economy on which they are founded, that many of them can be produced in the arts at pleasure. Painting is, in truth, little more than depicting on canvass the various optical errors, which we are habitually incurring.

To conclude,—the sense of sight differs materially in the scale of animals: in few is the organization more perfect or the function better executed than in man. Situated at the upper and anterior part of the body, it is capable of directing its regards over a large extent of surface; of converging the axes of the two organs upon objects in various situations, which cannot be effected by many animals; and it is very movable, and under the domination of a muscular apparatus of admirable arrangement. Still, it is not as delicately organized as in some animals, which are capable of seeing objects at a distance, that would be totally beyond the reach of the visual powers of man.

Like the other senses, it can be exerted *actively* and *passively;* hence the difference between simply *seeing* and *looking*. In the latter, the eye is directed to the object by the proper muscles; and it is not improbable but that the nerve may be aroused to a more accurate and delicate reception of impressions, as we have some reason for believing it to be in the case of the other senses. Like them, it admits of great improvement by education. The painter, and the worker in colours are capable of great discrimination, and detect the minutest shades of difference with the greatest facility.

In savage life, where the tracks or marks through the almost interminable forests, or over the pathless wilds, are the only guides, the greatest acuteness of vision is necessary; and, accordingly, we find the North American Indian, in this respect, eminently distinguished.

The mariner, too, accustomed to look out for land, or for a hostile sail, will detect it in the distant horizon long before it can be perceived by the landsman, and will appreciate its distance and course with signal accuracy,—education, in this case, not only communicating to his eye facility in being impressed, but improving the intellectual process, by which he arrives at the estimation of distances.

The five senses, which have been considered, constitute so many special nervous systems, each concerned in its appropriate function;

and, although conveying ideas of the external world to the brain, and connected with that organ, to a certain extent independent of it.

The generality of physiologists admit only these five; but some have suggested others, differing, in general, however, from the five, in having no organ at the surface of the body exclusively concerned in the function. Buffon regarded, as a *sixth sense*, the intense sensation experienced during the venereal act; but this can only be esteemed a peculiar variety of tact in the mucous membrane of the genital organs;—differing from ordinary tact in those parts, by requiring in both sexes a special condition of the membrane; and, in the male, one such, that the sperm, when excreted, shall make the necessary impression upon it; and, consequently, appertaining to both the external and internal sensations;—the state of the membrane being referable to the latter, and the effect of the contact of the sperm to the former.

Some have spoken of a *sense of heat and cold*:—this we have described under the head of tact; and others of a *muscular sense*, by which we acquire a knowledge of the motions to which muscular contractions give rise; and thus learn to apportion the effort to the degree of effect to be produced. The animal magnetizers, again, have suggested a sixth sense, to which man owes the capability of being acted upon by them; but this is entirely supposititious, and the facts admit of a more ready and satisfactory explanation.

A *sense of hunger* has been described as situated at the upper orifice of the stomach:—a *sense of thirst* in the œsophagus, and a *pneumatic sense* in the lungs; but all these are more properly internal sensations.

The German physiologists have suggested another sense, which they term *cœnæsthesis*, gemeingefühl, or *common feeling*, lebensgefühl, lebenssinn, individualitätssinn, and selbstgefühl.* This is not seated in any particular part of the body, but over the whole system, and hence termed gemein, or *common*. It is indicated by the lightness and buoyancy, which we occasionally experience, apparently without any adequate cause; as well as by a sense of lassitude and fatigue, unconnected with muscular action or disease. To it, likewise, belongs the involuntary shuddering, glow, or chilliness, experienced under similar circumstances. It is manifestly one of the numerous internal sensations felt by the frame, and every portion of it, according as they are in a perfect state of health, or labouring under some cause of irritation or oppression; but ought not to be regarded as an additional or sixth sense.

Again, it has been supposed, that certain animals may possess other senses than the five we have mentioned. Of this we can have no positive evidence. We are devoid of all means of judging of their sensations; and if we meet with an additional organ,

* "*Feeling of life, sense of life, sense of individuality*, and *self-feeling*."

which seems adapted for such a purpose, we have nothing but conjecture to guide us. Under the sense of touch it was remarked, that Spallanzani found the bat capable of avoiding obstacles placed, in its way intentionally, when the eyes, nostrils, and ears had been closed up, and it readily returns to the holes in the caverns to which it is habituated. Spallanzani and Jurine supposed, that this was owing to its being possessed of a sixth sense. We have seen, that the circumstance is explicable by these animals being possessed of unusual delicacy of touch.

Again, the accuracy with which migratory animals return to their accustomed haunts has given rise to the notion of a *sense of locality*, which is presumed to preside over this faculty. This is, however, in all probability, a cerebral faculty, and may fall under consideration hereafter.

Quadrupeds, the ape not excepted, have two bones in the face, in addition to those found in man. These contain the roots of the dentes incisores, when such are present, but they exist in animals also that are destitute of teeth. They are termed *ossa intermaxillaria, ossa incisoria*, and *ossa labialia*, and are situated, as their names import, at the anterior part of the jaw, and between the ossa maxillaria or jaw bones. Jacobson considers them to be an organ of sense, as they communicate with the exterior, and are largely supplied with vessels and nerves. Accordingly, this has been esteemed a sensitive apparatus, connected with the season of love in animals; and, by other naturalists, as a sense, intermediate between those of taste and smell, and intended to guide the animal in the proper selection of food. It need hardly be said, that this is all imaginary.

Adelon, it was remarked, makes two divisions of the external sensations:—those that convey information to the mind; and those that do not. The former have engaged attention; the latter will not occupy us long. They comprise but two—*itching* and *tickling*. Both of these occur in the skin and mucous membranes, and near the communication of the latter with the skin; or, in other words, near the termination of the outlets which they line.

Itching, however, is not always an external sensation,—that is, not always caused by the contact of a body external to it. It frequently arises from an altered condition of the tissue of the part in which it is experienced, as in cutaneous affections; in itching at the nose produced by irritation in the intestinal canal; itching at the glans penis in cases of calculi of the urinary bladder, &c., but commonly the sensation is caused by an extraneous body; and we are irresistibly led to *scratch*, however it may be produced. When it arises extraneously, it can generally be readily allayed; but, when dependent upon a morbid condition of the texture of the part, it becomes a true disease, and the source of much suffering. If the itching be accompanied with a feeling of motion, or of purring in the part, it is called *tingling.* This kind of purring also often occurs without the presence of itching.

Tickling or *titillation* is always caused by the contact of some extraneous substance, and is therefore a true external sensation. Although occurring in the skin, and in the commencement or termination of the mucous membranes, all parts are not equally susceptible of it: and some,—as the lining membrane of the genital organs, —are only, or chiefly so, under particular circumstances.

The sides, palms of the hands, and soles of the feet, are the most sensitive in this respect; not, perhaps, because the nerves are more numerous in those parts, but because, owing to thinness or suppleness of skin, or to other inappreciable circumstances, they are more susceptible of this kind of excitation. We find, too, that individuals differ as much as the parts of the body in this respect: some being *not ticklish*, or incapable of being thrown into the spasm, which the act, nay, even a threatening of the act, produces in others. Cases are on record, in which prolonged titillation has produced general convulsions, and even death. Lecat terms it an hermaphroditic sensation, inasmuch as, on the one hand, it excites laughter; and, on the other, is insupportable; and, consequently, appears to be intermediate between pleasure and pain.

INTERNAL SENSATIONS.

The external sensations make us acquainted with the universe surrounding us; and convey to the mind a knowledge of everything that can be, in any manner, inservient to our necessities. Such necessities have, however, to be suggested to the mind, before it reacts through the aid of the organs of prehension or otherwise, on external bodies, and this is accomplished by the agency of the *internal* or *organic sensations.*

Without the intervention of any external cause, every organ of the body is capable of transmitting to the brain a numberof different impressions, many of which impel the organ to acts, that are necessary not only for the preservation of the individual and of the species, but also for the perfect developement of the faculties. Such are the sensations of hunger and thirst; the impulse that leads to the union of the sexes; and the feeling we have of the necessity for intermission in the exercise of the muscles and of the intellect.

They have been divided into three species by some physiologists: the *first* arousing, or giving impulse to, the action of organs; and warning the brain of the different necessities of the system. They have been called *wants* or *instinctive desires.* Such are, hunger, thirst, the desire to evacuate the urine and fæces; that of respiration, the venereal appetite, *accouchement*, &c. They belong to those that arise, when it is necessary the organs should act.

The *second* species occur during the action of organs. They are often obscure, but sometimes very acute. Amongst these are the impressions accompanying the different excretions,—as that of the sperm, urine, &c. (although, as we have seen, these partly belong to the external sensations;) the impressions that warn us of our partial or general movements, of the progress of digestion, and of the intellectual labours.

The *last* species succeed to the action of organs, especially when such action has been too long continued; hence the inward feeling of *fatigue*, after too long exertion of the functions of the senses, of the intellectual and moral faculties, and of the organs of muscular motion; the *necessity of repose* after prolonged muscular exertion; and of *sleep*, to recruit the nervous system, and to fit it for the exertions it has to make during the waking condition.

The mode in which these sensations are effected is analogous to that of the external sensations. There is an *impression* on the part to which the sensation is referred; an action of *perception*, accomplished by the brain, and one of *transmission*, executed by a nerve passing between the two parts. The two last actions are probably executed in the same manner as they are in the external sensations. The first, or the mode in which the impression is effected, and the character of the impression itself, are much more obscure. In the external sensations, we can refer the impression to a known irritant:—special in some of the senses:—more general in others. We know, that light impresses the retina:—aerial undulations the acoustic nerve, &c.: but, in the internal sensations or *sentiments*, as some of the French writers term them, the source of the irritation is in some modified action of the part itself, in the very tissue of the organ, and hence the result is said to be *organic*. In the internal sensation of hunger, for example, the impression is engendered in the organ,—how, we know not,—is thence conveyed to the brain; and the sensation is not effected until the latter has acted. The same may be said of all the other internal sensations.

They differ, in other respects, from the external sensations. Whilst the latter may be entirely passive, or be rendered active by volition, without either action being the cause of particular pleasure or inconvenience, the former are but little influenced by volition. Constituting the wants—the instinctive desires—which impel to acts, that are necessary for the preservation and full developement of the individual and of the species, such independence is of course essential. On many of them, however, habit or accustomed volition has a certain degree of influence: and they can unquestionably be augmented or moderated by licentious indulgence or restraint. The influence of habit is exemplified by the regularity with which the appetite returns at stated intervals; and by the difference between that of the gourmand and of the temperate individual. It is most strikingly evidenced, however, in its influence over the moral wants; which may even spring up from social indulgence, and hence are not instinctive or organic: and we are every day compelled to notice the striking difference between the individual, who practises restraint upon his wants, and the libertine, who, like the animals surrounding him, gives unbridled sway to his natural and acquired appetites.

All the internal sensations, when satisfied or responded to in moderation, communicate a feeling of pleasure; but if resisted, pain results. If hunger be prolonged, there is a general feeling of uneasiness, which rapidly abates after food is received into the stomach in due proportion; but if satiety be produced, uneasiness follows; and this applies to all the appetites or wants.

The particular internal sensations will engage us, when the functions to which they belong fall under consideration. Like the external sensations they must, of course, administer to the intellect; to an extent which will be seen hereafter. Their influence and nature were entirely neglected, until of comparatively late years: but attention has been attracted to them chiefly by the labours of Cabanis and of Destutt-Tracy, and they now form subjects for interesting speculation with the metaphysician.

The *morbid sensations* belong more particularly to pathology: a brief notice of them will consequently be all that is necessary here. They are all comprised under the term *pain*. In its enlarged signification, this word, as is well known, means every uneasy or disagreeable sensation or moral affection: thus including sadness, anger, terror, as well as the painful impressions, felt in the extremities or trunks of the nerves. It is the latter only—or *physical pain*—that concerns us at present.

Like every other sensation, although it may be referred exclusively to the part impressed, pain requires the intervention of the brain: for if the nerves, proceeding from a part to that organ, be cut, tied, compressed, or stupefied by narcotics; or if the action of the brain itself be blunted from any cause, as by the use of opium, or by any compression, accidental or o[illegible]er, the sensation is no longer experienced. We can thus unders[illegible]nd why pain is less felt during sleep; and the astonishing cases of resistance to pain, which we witness in the lunatic, and in religious or other enthusiasts, who have been subjected to bodily torture. [illegible]ondition of the nervous system is the cause of the great [illegible]o impressions, which we witness in the nervous and hyste[illegible]

It is obvious, that pain may be either an e[illegible] or internal sensation, according as the cause of irritation is [illegible]aneous, or seated in the tissue of the organs; and that it must va[illegible] considerably, both as regards the precise irritant, and the part affected; hence the difference between the pain caused by a burn, and that by a cutting instrument; and the immense variety of pains to which the human frame is subject, the attentive study of which is so indispensable to the pathologist.

So much for the sensations. These we have seen are innumerable, for each sense is capable of myriads of different impressions.

We now pass to the consideration of those functions which enable man—though worse provided with means of defence and offence than the beasts surrounding him, and possessing no covering to protect him from the solar heat or the winter's cold—to provide himself means of defence; to render the animals around him subservient to his use; to cover his nakedness and protect himself against atmospheric changes; to devise every mechanical art; to fathom the laws, that govern the bodies by which he is surrounded, and to establish himself undisputed master of the earth.

OF THE MENTAL FACULTIES.

The external senses convey to the brain the different impressions, made upon them by surrounding bodies; but, of themselves, they would be unable to instruct the mind regarding the universe. It is necessary, that the brain should act before any perception, any idea of them, can exist. The *mental faculties*, in other words, convert the impressions into such ideas. The internal sensations, on the other hand, consist, as we have seen, of the numerous wants and appetites, necessary for the preservation of the individual and of the species. In addition to these, man possesses another series of faculties, which influence his character and disposition, and direct his social existence:—these are the *affective* or *emotive faculties*, or the *faculties of the heart.*

The study of these different mental and moral phenomena embraces, what has been called, *psychology*, from a notion that they are exclusively dependent upon the mind. This notion was, at one time, universal, and hence the appellation *metaphysician*, applied to such as were considered to proceed in their investigations of those subjects beyond what was [illegible]hysical, material, or corporeal.

There is no subject, w[illegible]ich has given occasion to so much excitement and controversy, as that of the connexion of the mental faculties with the encephalon. "It has unfortunately happened," says Dr. Bostock, "[illegible]ject, which is one of great interest and curiosity, has [illegible]n viewed with that philosophical spirit, which should a[illegible]ect our investigations, and by which alone we can expect t[illegible] at truth. It is admitted, that certain errors may be so interv[illegible] with our accustomed associations, on topics connected with mo[illegible]s and religion, as to render it doubtful, on some occasions, how far we ought to attempt their removal: but if this concession be made on the one hand, it is incumbent upon us, on the other, not to inflame the prejudices, which may exist on these topics, but to use our endeavours to correct all undue excitement, and thus to bring the mind into that tranquil state, which may enable it to receive truth without the fear of injury."

In such a spirit ought every discussion on this interesting subject to be conducted; and in such a spirit will the few remarks, which we have to make, be offered.

The chief opinions, which have been indulged on this subject, are,—1st. That all the mental phenomena are immaterial and the exclusive product of the mind. 2dly. That the sentient principle, within us, requires the intervention of an organ, through which it acts; in other words, that mind is a principle superadded to organization; and 3dly. That where there is no organization there is no perception:—that wherever an organized structure, like the brain, exists, perception exists; that where the organization is imperfect, perception is imperfect; where the organization is sound and vigorous, perception is clear and vigorous; where it is impaired, perception is impaired; and that, when the organization ceases, perception appears to cease also. This last view is *materialism*. It supposes that a certain condition of matter is capable of thinking, reasoning, and understanding.

The doctrine,—that our intellectual and moral acts are superadded to organization, during life, and that there is an organ of the body concerned in their manifestation,—is the one embraced by the generality of physiologists, and is most consistent with reason and analogy; it is but justice, however, to admit that the views of those, who consider that a certain organization produces thought, are not deserving of the anathemas which have been directed against them on the score of irreligion. The charge would rather apply to those who could doubt the power of Omnipotence to endow matter with such attributes.

Were the mental and moral phenomena the exclusive products of the immaterial principle within us, they would hardly form subjects for physiological inquiry. That they are allied to organization is inferred form the following reasons. As they constitute so many functions, were they not provided with an organ or organs, they would form so many exceptions;—each of the sensations requiring an organ for its accomplishment. Again, our inward feeling induces us to refer them to a particular part of the frame: whilst thought appears to us to be affected within the head, the chief effects of the passions are felt in the region of the heart or stomach. They are, moreover, not the same in every individual. One man is a poet, another a mathematician; or one is benevolent, another cruel. If these faculties were the exclusive product of the mind, and of course not to be ascribed to diversity of organization, we should have to admit, that each individual has a different immaterial principle, and of course, that there must be as many kinds as there are individuals. Lastly.—The faculties vary in the same individual according to circumstances. They are not the same in the child as in the adult; nor in the adult as in one advanced in life; in health as in disease; in waking as in sleep. During an attack of fever they become temporarily deranged, and permanently so in all the varieties of insanity. These facts are inexplicable under the doctrine, that they are the exclusive product of the mind or immaterial principle. An immaterial or spiritual principle ought to be immutable; yet we should have to suppose it capable of alteration; of growing with the growth of the body, and of becoming old with it; of being awake or asleep; sound or diseased. All these modifications are impressed by varying organization—of the brain in particular.

We may conclude, then, that the intellectual and moral faculties are not the exclusive product of the mind, but that they require the intervention of an organ.

That this organ is the encephalon, or a part of it—the brain—is announced by many circumstances.

In the *first* place, they are phenomena of sensibility, and hence we should be disposed to refer them to a nervous organ; and being the most elevated phenomena of the kind, to the highest of the nervous organs.

In the *second* place, inward feeling induces us to refer them thither. We not only feel the process there, during meditation, but the sense of fatigue, which succeeds to hard study, is experienced there likewise.

The brain, again, must be in a state of integrity, otherwise the faculties are deranged; or, for the time, abolished. In fever, the brain becomes affected directly or indirectly, and the consequence is —perversion of the intellect, in the form of delirium. If the organ be more permanently disordered, as by the pressure of an exostosis or of a tumour, or by some alteration in its structure or functions—less appreciable in its nature—insanity, in some of its forms, may be the result.

In serious accidents to the encephalon, we observe the importance of the cerebral organ to the proper exercise of the mental faculties most clearly evinced. A man falls from a height, and fractures his skull. The consequence of this is depression of a portion of bone, which exerts a degree of compression upon the brain; or extravasation of blood from some of the encephalic vessels, attended with similar results. From the moment of the infliction of the injury, the whole of the mental and moral manifestations are suspended, and do not return until the compressing cause is removed, by the operation of the trephine. Richerand cites the case of a female, who had a portion of the brain accidentally exposed, and in whom it was found, that pressure upon the brain completely deprived her of all consciousness, which was not restored until the pressure was removed. A similar case is related by Lepelletier, de la Sarthe. A patient of a Dr. Pierquien had an extensive caries of the os frontis, with a perforation of the bone, which exposed the brain covered by its membranes. When she slept soundly the organ sank down: when she dreamed, or spoke with feeling, a turgescence and marked oscillations were perceptible; when the brain was pressed upon she stopped in the middle of a sentence or of a word, and when the pressure was removed, she resumed the conversation, without any recollection of the experiment to which she had been subjected.

We notice, however, an important difference in the effect, according to the suddenness or tardiness with which the pressure is produced. Whilst a sudden compression suspends the intellectual and moral manifestations for a time, slow pressure, produced by the gradual formation of a tumour, may exist without exhibiting, in any manner, the evidences of its presence. Accordingly, the anatomist is sometimes surprised to discover such morbid formations in the brains of those who have never laboured under any mental aberration.

A negative argument in favour of this function of the brain has been deduced from the fact, that disease of other portions of the body, even of the principal portions, may exist and pass on to a fatal termination, leaving these faculties almost wholly unimpaired. Such is proverbially the case with phthisis pulmonalis, the subject of which may be flattering himself with hopes never to be realized, and devising schemes of future aggrandizement and pleasure, until within a few hours of his dissolution.

The intellectual faculties differ in each individual, and vary materially with the sex. The brain is, in all these cases, equally different. Much may depend upon education; but it may, we think, be laid down as an incontrovertible position, that there is an original difference in the cerebral organization of the man of genius and of him who is less gifted; and, as a general principle, that in the former the brain is much more developed than in the latter. Whilst the brain of the man of intellect may measure from nineteen to twenty-two inches in circumference, that of the idiot frequently does not exceed thirteen, or is not greater than in the child one year old.

It was an ancient observation, that a large developement of the anterior and superior parts of the head is a characteristic of genius; and, accordingly, we find, that all the statues of the sages and heroes of antiquity are represented with high and prominent foreheads. In the older poets, we meet with many evidences, that the height of the forehead was regarded as an index of the intellectual or moral character of the individual—Thus, Shakspeare:

> "We shall lose our time,
> And all be turn'd to barnacles, or to apes,
> With foreheads villanous low."
>
> *Caliban, in 'Tempest.'*—Act iv.

And again:—

> Ay, but her forehead's low, and mine's as high."
>
> *Julia, in the 'Two Gentlemen of Verona.'*—Act iv.

The relation between the size of the head and the mental manifestations has, indeed, interwoven itself into our ordinary modes of speech.

Perhaps, as a general observation, it may be found true, that the mental capacity is in a ratio with the size of the brain, compared to that of the rest of the body. It is obvious, however, that to this there must be numerous exceptions, and that independently of bulk there may be an organization, which may be productive of the same results, and in which the largely developed organ may be greatly deficient. Size is only one of the elements of the activity of an organ.

The difference between the *moral* of the male and female is signal; and there is no less in the shape of the encephalon in the two sexes. Observation, not only by anatomists but by sculptors and painters, shows, that the superior and anterior parts of the brain are less developed in the female, whose forehead is, therefore, as a general rule, smaller; whilst the posterior parts are larger than in the male. In the system of Gall, the anterior and superior parts are considered to be connected with the intellectual manifestations, which are more active in man; whilst the posterior are concerned in the softer feelings, which predominate in the character of the female.

The mental and moral faculties vary in the same individual, according to age, health, and disease; and in the waking and sleeping state. In all these conditions, we have reason to believe, that the state of the encephalon is as various. The anatomist notices a manifest difference between its organization in the infant and in the adult or the aged. Like the other organs of the body, it is gradually developed until the middle period of life; after which it decays along with the rest of the frame. Our acquaintance with the minute organization of the body does not enable us to say on what changes these differences are dependent. We see them only in their results. By the minutest examination of the special nerves of the senses we are incapable of saying, why one should be able to appreciate the contact of sapid bodies—another that of light, &c.

During sleep, again, in which the functions of the brain are more or less suspended, the condition of the organ is modified; and mania or delirium probably never occurs, without the physical condition of the brain having undergone some change, directly or indirectly. It is true, that, on careful examination of the brains of the insane, it has often happened that no morbid appearance has presented itself; but the same thing has been observed on inspecting those, who have died of apoplexy or paralysis, in which cases, not a doubt is entertained that the cause is seated in the encephalon, and that it consists in a physical alteration of its tissue. These are a few of the cases, which make us sensible of the limited nature of our powers of observation. They by no means encourage, in the most sceptical, the belief, that the tissue of the organ is not implicated. The investigations of the morbid anatomist consequently afford us but few data, on which to form our opinions on this subject.

The effect of intoxicating substances must be mainly exerted on the brain. When taken in moderation, we find all the faculties excited; but, if pushed too far, the intellectual and moral manifestations become perverted. This can only be through the action of those substances upon the cerebral organ. We can thus understand, how regimen may cause important modifications in the brain. Climate has probably a similar influence: hence the difference between the characters of different nations and races. The skull of the Mongol is strikingly different from that of the Kelto-Goth or of the Ethiopian; and the brain, as well as its functions, exhibits equal diversity.

Again, it has been argued, that the facts we notice in the animal kingdom are in favour of the brain being the organ concerned in the manifestations of the mind; that, if each animal species has its own psychology, in each the encephalon has a particular organization; and that, in all those which exhibit superior powers, the brain is found large and more complicated. To a great extent this is doubtless true. Nothing is, indeed, more erroneous than the notion, that even sensibility to pain is equal in every variety of the animal creation. As we descend in the scale, we find the nervous system becoming less and less complicated, until ultimately it assumes the simple *original* character, which has laid the foundation for one of the divisions of Sir Charles Bell's system; and, although it is impossible to change places with the animal, we have the strongest reasons for believing, that their sensibility diminishes as we descend; and that the feeling, expressed by the poet, that the beetle, which we tread upon—

> "In corporal sufferance finds a pang as great,
> As when a giant dies"—

however humane it may be, is physiologically untrue. The frog will continue sitting, apparently unconcerned, for hours after it has been eviscerated; the tortoise walks about after losing its head; and the polypus, when divided by the knife, forms so many separate animals. Redi removed the whole of the brain from a common land tortoise: the eyes closed to open no more, the animal walked as before, but, as it were, groping its way for want of vision. It lived nearly six months after. All have noticed the independence of the parts of a wasp, when the head has been severed from the body. The head will try to bite, and, for a considerable period, the abdomen will attempt to sting. An illustrative instance of this kind occurred to Dr. Harlan, of Philadelphia. He cut off the head of a rattlesnake, and grasping the part of the neck, attached to the head, with his finger and thumb, the head twisted itself violently, endeavouring to strike him with its fangs. A live rabbit was afterwards presented to the head, which immediately plunged its fangs deep into the rabbit; and when the tail was laid hold of, the headless neck bent itself quickly round as if to strike him.

The instances of a similar kind, which occur to the naturalist, are numerous and interesting; and afford signal evidence of creative wisdom, in endowing the frames of those beings of the animal kingdom, that are most exposed to injury and to torture, with a less sensible organization.

On all the above accounts, then, we may conclude,—that the brain is the organ, through which the mind acts, in the production of the different mental and moral manifestations.

Yet, amongst those who admit the accuracy of this conclusion, a difference of sentiment exists. Some conceiving that other organs participate in the function. Some have ascribed to each of the known temperaments as many intellectual and moral dispositions. Others have affirmed, that, if the brain be manifestly the organ of the intellect, the passions must be referred to the organs of internal or organic life; whilst others, again, have considered the brain as a great central apparatus, for the reception and elaboration of the different impressions, made upon the external senses; thus conceiving the latter to be direct agents in the execution of the function, as well as the brain.

The influence of the temperaments upon the mental and bodily powers is much less invoked at the present day than it was of old. The ancients regarded organized bodies as an assemblage of elements, endowed with different qualities, but associated and combined so as to moderate and *temper* each other. Modern physiologists mean, by the term, the reaction of the different organs of the body upon each other, consistent with health; so that if one set or apparatus of organs predominates, the effect of such predominance may be exerted over the whole economy. In the description of the temperaments, in different authors, we find a particular character of intellectual and moral faculties assigned to each. The man of the *sanguine* temperament is described as of ready conception, retentive memory, and lively imagination, inclined to pleasure, and generally of a good disposition, but inconstant and restless. He of the *bilious*, on the other hand, is said to be hasty, violent, ambitious, and self-willed; whilst the *lymphatic* bestows feeble passions, cold imagination, tendency to idleness; and the *melancholic* disposes to dulness of conception, and to sadness and moroseness of disposition.

Gall has animadverted on this assignment of any intellectual or moral faculty to temperament. If we look abroad, he affirms, we find the exceptions more numerous than the rule itself; so numerous, indeed, as to preclude us from establishing any law on the subject; and, moreover, the idiot, who possesses a temperament like other persons, has no intellectual faculties. The temperament doubtless influences the brain within certain limits, as it does other functions: this, he suggests, it does probably by impressing them with a character of energy or of languor, but without, in any respect, regulating the intellectual sphere of the individual; and it may be regarded as one of the media of connexion between the mind and the body.

Bichat, again, maintained, that whilst the encephalon is evidently the seat of the intellectual functions, the organic nervous system, and, consequently, the different organs of nutrition, which are supplied from this system, are the seat of the emotions or passions. That distinguished physiologist, than whom, as Corvisart wrote to the First Consul, in announcing his death, "*personne en si peu de temps n'a fait tant de choses et aussi bien*," rests his views upon the three following considerations:—1*st.* That whilst inward feeling induces us to refer the intellectual acts to the brain, the passions are felt in the viscera of the thorax or abdomen. 2*dly.* That the effects of intellectual labour are referred to the encephalon, as indicated by the redness and heat of the face and the beating of the temporal arteries, in violent mental contentions, &c.; whilst the passions affect the organic functions, the heart is oppressed, and its pulsations are retarded or suspended; the respiration becomes hurried and interrupted; the digestion impeded or deranged, &c.; and, 3*dly.* That whilst our gestures and language refer the intellect to the encephalon, they refer the emotions to the nutritive organs. If we wish to express any action of the mind, or if we are desirous of recalling something that has escaped the memory, the hand is carried to the head, and we are in the constant habit of designating a strong or weak intellect by the terms a "strong or weak or long *head;*" and we say that the possessor has "much or little *brain.*" On the other hand, if we are desirous of depicting the passions, the hand is carried to the region of the stomach or heart; and the possessor of benevolent or uncharitable sentiments is said to have a good or bad *heart.*" Bichat properly adds, that this idea is not novel, inasmuch as the ancients conceived the seat of the passions to be in the epigastric centre; that is, in the nervous plexuses, situated in that region; and he remarks, that, amidst the varieties presented by the passions, according to age, sex, temperament, idiosyncrasy, regimen, climate, and disease, they are always in a ratio with the degree of predominance of the different nutritive apparatuses; and he concludes with a deduction, which ought not to have been hazarded without the fullest reflection—that as the functions of the nutritive organs, in which he ranges the passions, are involuntary, and consequently uninfluenced by education, education can have no influence over the passions, and the *disposition* is consequently incapable of modification.

The answer of Gall and Adelon to the views of Bichat appears to us irrefragable. How can we conceive that viscera, whose functions are known, and which differ so much from each other, are the agents of moral acts? The passions are sensorial phenomena, and like all phenomena of the kind must be presumed to be seated in essentially nervous organs.

Again, when an injury befalls the brain, and the intellectual faculties are perverted or suspended by it, the same thing happens to the affective faculties; and if the viscera fulfil the high office assigned to them, why are not the passions manifested from the earliest infancy, a period when the viscera are in existence and very active?

The argument of Bichat—that the phenomena which attend and succeed to the passions, are referable to the organs of internal life—is not absolute. The functions of animal life are frequently disturbed by the passions, as well as those of organic life. It is not uncommon for them to induce convulsions, mania, epilepsy, and other affections of the encephalon. The effect here, as Adelon remarks, is mistaken for the cause. The heart certainly beats more forcibly in anger, but the legs fail us in fear; and if we refer anger to the heart, we must, by parity of reasoning, refer fear to the legs. By reasoning of this kind, the passions might be referred to the whole system, as there is no part which does not suffer more or less during their violence. The error arises from our being impressed with the most prominent effect of the passion—the feeling accompanying it—and this is the cause of the gesture and the descriptive language, to which Bichat has given unnecessary weight in his argument.

If, then, the views of Bichat, regarding the seat of the passions, be unfounded, the mischievous doctrine deduced from them—that they are irresistible, and cannot be modified by education, falls to the ground. His notion was, that the nutritive organs are the source of irritative irradiations, which compel the brain to form the determinations that constitute the passion, and to command the movements by which it is appeased or satisfied. A similar view is embraced by Broussais, who, however, conceives, that the passions can be fomented and increased by attention, until they become predominant.

Daily experience shows us the powerful effect produced on the passions by a well-directed moral restraint. How many gratifying instances have we of persons, whose habitual indulgence of the lowest passions and propensities had rendered them outcasts from society, having become restored to their proper place in the community by exerting the due control over their vicious inclinations and habits? We can not only curb the expression of the passions, as we are constantly compelled to do in social intercourse; we can even modify the internal susceptibility, by well-directed habits of repression.

Lastly. Many physiologists, we have seen, have considered the brain as a great nervous centre for the reception and elaboration of the different impressions, conveyed thither by the external senses; and absolutely requiring such impressions for the mental manifestations. They consequently rank, amongst the conditions necessary for such manifestations, not only the brain, which elaborates them, but the parts, that convey to it the impressions or materials on which it has to act; and they conceive, that a necessary connexion exists between these two orders of parts.

The supporters of these opinions ascribe the differences, observed in the intellectual and moral faculties of different individuals, as much to diversity in the number and character of the impressions, as to differences in the encephalon itself.

They do not all, however, agree as to the source of the impressions, which they conceive to be the *raw material* for the intellectual and moral manifestations. Condillac and his school admit only one kind;—those proceeding from the external senses; and which they term *external impressions.* Cabanis, on the other hand, in addition to these, admits others proceeding from every organ in the body, which he terms *internal impressions*, in contradistinction to the first.

The school of Condillac set out with the maxim ascribed to Aristotle, "*nihil est in intellectu quod non prius fuerit in sensu;*" and they adopt, as an elucidation of their doctrine, the ingenious idea of Condillac—of a statue, devoid of all sensation, which is made to receive each of the five senses in succession; and which, he attempts to show, from the received impressions, can develope the different intellectual and moral faculties. All these, he affirms, are derived from the impressions made on the external senses; and he considers, that the whole of human consciousness is mere sensation variously transformed.

The views of Condillac have been largely embraced, with more or less modification; and, at the present day, many metaphysicians believe, that the impressions of the senses are the necessary and exclusive materials of all the intellectual acts.

Condillac's case of the statue seems, however, to be by no means conclusive. It must, of course, be possessed of a centre for the reception of the impressions made upon the different senses, otherwise no perception could occur; and if we can suppose it possible for such a monstrous formation to exist, as a being totally devoid of the external senses, such a being must not only be defective in the nerves which, in the perfect animal, are destined to convey the impressions to the brain, but probably in the cerebral or percipient part likewise. From defective cerebral conformation, therefore, the different mental phenomena might not be elicited.

If, however, we admit the possibility of the cerebral structure,—particulary those portions that are especially concerned in the function of thought,—being properly organized, it appears to us, that certain mental or moral manifestations ought to exist. Of course, all knowledge of the universe would be precluded, because deprived of the *instruments* for obtaining such knowledge; but the brain would still act, as regarded the internal sensations. In order, that such a being may live, he must be supplied with the necessary nourishment; he must possess all those internal sensations or wants that are inseparably allied to organization; he must consequently feel the desires of hunger and thirst: but we have seen, that these sensations require the intervention of the brain, as much as the external sensations. Supposing him, again, to survive the period of puberty, he must experience the instinctive changes, that occur at this period, and which are doubtless dependent upon encephalic organization. In this assumed case, then, a certain degree of mental action might exist; and, under the supposition of a properly organized brain, ideas—limited, it is true, in consequence of the privation of the ordinary inlets of knowledge—might be formed; and memory, imagination, and judgment, be compatible within certain limits.

The objections to the idea, that the intellectual and moral sphere of man and animals is proportionate to the number and perfection of the external senses are overwhelming. Many animals have the same number of senses as man, and frequently have them more perfect; yet, in none, is the mental sphere co-extensive. The idiot, too, has the external senses as delicate as the man of genius, and often much more so; many of those, of the greatest talents, having the senses extremely obtuse. It has been already remarked, that the superiority of the human intellect has been referred entirely to the sense of touch, and to the happy organization of the human hand; but the case of Miss Biffin, more than once referred to, and that of the young artist cited by Magendie, completely negative this presumption.

The senses are important secondary instruments, indispensably necessary for accomplishing certain faculties of the mind; but, in no way, determining its power.

The example of the deaf and dumb is illustrative of this matter. If a child be born deaf, he is necessarily dumb, inasmuch as he is unable to hear those sounds, which, by their combination, constitute language, and cannot therefore imitate them; yet this connexion between the functions of hearing and speech was not well known to the ancients. For a length of time, these objects of compassionate interest were esteemed to be beyond the powers of any kind of intellectual culture, and were permitted to remain in a state of the most profound ignorance. The ingenuity of the scientific philanthropist has, however, devised modes of instruction, by which their mental manifestations have been exhibited in the most gratifying manner, and in one which proves, that the sense of hearing is not absolutely necessary for mental developement; and that its place may be supplied, to a great extent, by the proper exercise of others.

The deaf and dumb, being deprived of the advantages of spoken language, are compelled to have recourse to the only kind available to them—that addressed to the eye. In this typical way, by a well-devised system of instruction, they can be taught to preserve their ideas, and to multiply them, as we do by the two combined—the spoken and written language—without one or other of which the human mind would have remained in perpetual infancy. In this way, the deaf and dumb have not only our ideas, but the same words to convey them to others.

Yet the deaf and the dumb are not so much objects of our commiseration as those who have been deprived, from birth or from early infancy, of the senses of sight and hearing, and who have thus been devoid of two of the most important inlets for the entrance of impressions from the surrounding world. In such case, it is obvious, they are shut out from all instruction, except what can be afforded by the senses of touch, smell and taste; yet even here we have the strongest evidence of independent intellect.

One of the most striking cases of this kind is that of the Scottish boy Mitchell, the object of much interest to Spurzheim and to Dugald Stewart, both of whom have described his case in their writings. It is matter of uncertainty, whether either his deafness or blindness was total. The evidences of the sensation of sound were, in a high degree, vague and unsatisfactory, but he gave more convincing proofs of the possession of partial vision. He could, for example, distinguish day from night; and, when quite young, amused himself with looking at the sun through crevices in the door, and by kindling a fire. At the age of twelve, the tympanum of both ears was perforated, but without any advantage. In his fourteenth year, the operation for cataract was performed on the right eye, after which he recognized more readily the presence of external objects, but never made use of his sight to become acquainted with the qualities of bodies. Before, and after, this period, red, white, and yellow particularly attracted his attention. The senses, by which he judged of external bodies, were those of touch and smell. His desire to become acquainted with objects was signal. He examined everything he met with, and every action indicated reflection. In his infancy, he smelt at every one who approached him, and their odour determined his affection or aversion. He always recognized his own clothes by their smell, and refused to wear those which he found to belong to others. Bodily exercises, such as rolling down a small hill, turning topsy-turvy, floating wood or other objects on the river, that passed his father's house, gathering round, smooth stones, laying them in a circle, and placing himself in the middle, or building houses with pieces of turf, &c. were always a source of amusement to him. After the operation on his right eye, he could better distinguish objects. His countenance was very expressive, and his natural language was not that of an idiot, but of an intelligent being. When hungry, he carried his hand to his mouth, and then pointed to the cupboard, where the provisions were kept; and, when he wished to lie down, he reclined his head on one side upon his hand, as if he wished to lay it upon the pillow. He easily recollected the signification of signs, that had been taught him, all of which were of course of the tactile kind. To make him comprehend the number of days before an event would happen, they bent his head as a sign, that he would have to go to bed so many times. Satisfaction was expressed by patting him on the shoulder or arm, and discontent by a sharp blow. He was sensible to the caresses of his parents, and susceptible of different emotions—of hatred, passion, malice, and the kindlier feelings. He was fond of dress, and had great fears of death, of the nature of which he had manifestly correct notions.

Mitchell's case has been pregnant with interest to the metaphysician, but it is not so elucidative as it would have been had the privation of the senses in question been total.

There is, at present, in the American Asylum at Hartford in Connecticut, a being, not less deserving of attention than the one to whom allusion has just been made. Her name is Julia Brace. She is the daughter of John and Rachel Brace, natives of Hartford, and was born in that town in June, 1807; so that she is now, (1835,) twenty-eight years old. At four years of age, she was seized with typhus fever; was taken sick on the evening of Monday, November 29, 1811, and, on the Saturday morning following, became both *blind* and *deaf*.

Prior to her illness, she had not only learned to speak, but to repeat her letters, and to spell words of three or four syllables; and, for some time after the loss of her sight and hearing, she was fond of taking a book, and spelling words and the names of her acquaintances. She retained her speech pretty well for about a year, but gradually lost it, and appears to be now condemned to perpetual silence. For three years, she could still utter a few words, one of the last of which was "*mother*." At first she was unconscious of her misfortune, appearing to think, that a long night had come upon the world; and often said, "It will never be day." She would call upon the family to "light the lamp," and was impatient at their seeming neglect, in not even answering her. At length, in passing a window, she felt the sun shining warm upon her hand, and pointed with delight to indicate that the sun shone. From the January after her illness, until the following August, she would sleep during the day, and be awake through the night; and it was not until autumn, by taking great pains to keep her awake during the day, that she was set right. At present, she is as regular, in this respect, as other persons. From the period of her recovery, she seemed to perceive the return of Sabbath; and, on Sunday morning, would get her own clean clothes, and those of the other children. If her mother was reading, she would find a book, and endeavour to do so likewise. Even now, the intervention of a day of fasting or thanksgiving will confuse her reckoning, and some time elapses before she gets right.

During the first winter after her recovery, she was irritable almost to madness; would exhibit the most violent passion, and use the most profane language. The next summer she became calmer; and her mother could govern her, to some extent, by shaking her, in sign of disapprobation; and stroking or patting her head, when she conducted herself well. She is now habitually mild, obedient, and affectionate.

During the first summer after her illness, she was very unwilling to wear clothes and would pull them off violently. At length her mother took one of her frocks and tried it on her sister, with a view of altering it for her. Julia had ever been remarked for her sense of justice in regard to property. This seemed to be awakened, and she took the frock and put it on herself. After this, she was willing to wear clothes, and even cried for *new ones*. She has ever since been fond of dress. At nine years of age, she was taught to sew; and, since that time, has learned to knit. She has been resident for several years in the American asylum at Hartford, where she is supported in part, by the voluntary contributions of visitors; and, in part, by her own labours in sewing and knitting. A language of palpable signs was early established, as a means of communication with her friends; and this has been so improved as to be sufficient for all *necessary* purposes. Her countenance, as she sits at work, is said to exhibit the strongest evidence of an active mind and a feeling heart: "thoughts and feelings," says a writer who describes her case, "seem to flit across it like the clouds in a summer sky: a shade of pensiveness will be followed by a cloud of anxiety or gloom; a peaceful look will perhaps succeed; and, not unfrequently, a smile lights up her countenance, which seems to make one forget her misfortunes. But no one has yet penetrated the darkness of her prison house, or been able to find an avenue for intellectual or moral light. Her mind seems, thus far, inaccessible to all but her Maker."

An equally extraordinary example is cited by Dr. Abercrombie, from the Medical Journals of recent date. A gentleman in France is asserted to have lost every sense except the feeling of one side of his face; yet his family acquired a method of holding communication with him, by tracing characters upon the part, which retained its sensation.

How strongly do these cases demonstrate the independence of the organ of intellect; requiring, indeed, the external senses for its perfect developement, but still capable of manifesting itself, without the presence of many and probably of any of them; and how inaptly, although humanely, does the law regard such beings. "A person," says Blackstone, "born *deaf*, *dumb*, and *blind*, is looked upon by the law as in the same state with an idiot, he being supposed incapable of any understanding, as wanting all those senses which furnish the human mind with ideas." But if he *grow* deaf, dumb, and blind, not being *born* so, he is deemed *non compos mentis*, and the same rules apply to him as to other persons supposed to be lunatics.

With regard to the deaf and dumb, they are properly held to be competent as witnesses, provided they evince sufficient understanding, and to be liable to punishment for a breach of the criminal laws.

Cabanis embraces the views of Condillac regarding the external senses; but he thinks, that the impressions from these are insufficient to constitute the *matériel* of the mental and moral manifestations. In confirmation of this opinion, he observes, that the young infant and animals, at the very moment of birth, frequently afford evidences of complicated intellectual processes; and yet the external senses can have been scarcely at all impressed. How can we, he asks, refer to the operation of the external senses the motions of the fœtus in utero, which are perceptible to the mother, for the latter half of utero-gestation; or the act of sucking executed from the first day of existence? Can we refer to this cause the fact of the chick, as soon as it is hatched, pecking the grain that has to nourish it? or that, so frequently quoted from Galen, of the young kid, scarcely extruded from the maternal womb, which was able to select a branch of the cytisus from other vegetables presented to it?

Man and animals, continues Cabanis, during the course of their existence, experience mental changes as remarkable as they are frequent: yet nothing in the condition of the senses can account for such difference. For example, at the period of puberty, a new appetite is added; and this, even, when the being is kept in a complete state of isolation. This, he argues, it is impossible to refer to any change in the external senses; which, if they furnished the materials at all, must have been doing so from early infancy; and he concludes, that the difference observable in the mental manifestations, according to sex, temperament, climate, state of health or disease, regimen, &c. cannot be referable to the senses, as they remain the same; and that, consequently, we must look elsewhere for the causes of such difference.

These Cabanis conceives to be, the movements by which the organs of internal life execute their functions. Such movements, he says, although deep-seated and imperceptible, are transmitted to the brain, and furnish that organ with a fresh set of materials. At puberty, for example, when the testicles become developed, and their function is established by the secretion of the sperm, the organic movements in the process of this secretion, are the materials of the new desires, which appear at that age. These impressions Cabanis calls *internal*, in contradistinction to the *external*, or those furnished by the senses; and he considers, that, whilst the external senses serve as the base of all that we include under the term *intellect*, the internal impressions are the materials of what are called *instincts;* and, as the organs of internal life, whence the internal impressions proceed, vary more than the senses, according to age, sex, temperament, climate, regimen, &c. it is more easy, he thinks, to find in them organic modifications, which coincide with those exhibited by the mind under these various circumstances.

In proof of these opinions, Cabanis adduces, besides others, the following specious affirmations. *First.* As the venereal appetite appears in man and animals synchronously with the developement of the testicles, and is never exhibited when the testicles are removed in infancy, we have reason to believe, that the impressions, which constitute the materials for this new catenation of ideas, must proceed from the testicle. *Secondly.* Numerous facts demonstrate, that the condition of the uterus has much influence on the mental and moral manifestations of the female. For example, the period of the developement of that organ is the one at which new feelings arise, and when the whole of these manifestations assume more activity; and there is generally a ratio between their activity and that of the uterus. If the state of the uterus be modified, as it is at the menstrual period, or during pregnancy, or after delivery, the mind is so likewise. All these facts ought to induce a belief, he thinks, that impressions are continually emanating from this organ, which, by their variety, occasion the diversity in the state of mental and moral faculties, observed in these different cases. *Thirdly.* It is impossible in the *hypochondriac* and *melancholic* constitutions, to mistake the influence exerted upon the mind by the abdominal organs; according as these organs execute their functions more or less perfectly, the thinking faculty is more or less languid or brilliant; and the affections are more or less vivid and benevolent, or the contrary; hence the expressions *melancholy** and *hypochondriasis*,† assigned to the state of mind characterizing these constitutions, and which denote that the cause must be referred to the organs of the abdomen. The origin of the alternations of inactivity and energy in the intellect, of benevolent and irascible fits of humour, as well as of insanity, are also referable, he says, to the abdominal viscera.

Hence, Cabanis concludes, it is evident, that the abdominal organs are to the brain the source of fortuitous and anormal impressions, which excite it to irregular acts; and is it not, he asks, probable, that what takes place in excess, in these morbid movements, may happen to a less and more appropriate extent in the state of health; and that thus impressions may emanate, in a continuous manner, from every organ of the body, which may be indispensable to the production of the mental and moral faculties?

Cabanis, therefore, considers, that the axiom of Aristotle should be extended; and that the statue of Condillac is incomplete, in not having internal organs for the emanation of the internal impressions, which are the materials of the instincts.

In this way he accounts for the instincts, which, by some metaphysicians, have been looked upon as ordinary judgments, so rapidly executed, that the process has ceased from habit to be perceptible.

Finally, he remarks there is a ratio between the duration and intensity of the intellectual results and the kind of impressions, which have constituted the materials of them. All the mental and moral acts, for instance, that are derived from impressions engendered in the very bosom of the nervous system or in the brain,—such as those of the maniac,—are the strongest and most durable. After these come the *instincts*, of which the internal impressions are the materials. They are powerful and constant. Lastly; the acts of the *intellect* are more transient, because they emanate from the

* From μελας, black, and χολη, bile. † Disease of the hypochondres.

external impressions, which are themselves fickle, and somewhat superficial.

According to the views, then, of Cabanis and his followers, amongst the organic conditions of the mental and moral manifestations must be placed, not only the encephalon and the external senses, but the different organs of the body, which furnish the different internal impressions.

The influence of the external senses on the intellectual and moral developement has already been canvassed: we have seen, that they are only secondary instruments for making us acquainted with external bodies, but in nowise regulating the intellectual or moral sphere. The notion of internal impressions is ingenious, and has led to important improvements in the mode of investigating the different mental and moral phenomena. It was suggested, as we have seen, by Cabanis, in consequence of the external senses appearing to him insufficient to explain all the phenomena.

By Gall, Adelon, and others, however, all these cases are considered explicable, by the varying condition of the brain itself. In the fœtus in utero, in the new-born animal, there are already parts of the brain, they say, sufficiently developed and capable of action; and, accordingly, we witness the actions to which reference has been made by Cabanis; and if the intellectual and moral manifestations vary according to sex, temperament, climate, regimen, state of health, &c. it is because the encephalon is, under these circumstances, in different conditions.

The chief facts, on which Cabanis rests his doctrine, are,—the coincidence between the developement of the testicle and the appearance of the venereal appetite; and the suppression of this appetite after castration. It must be recollected, however, that these are not the only changes, that happen simultaneously at puberty. The voice also assumes a very different character; but the change in the voice is not a cerebral phenomenon. It is dependent upon the developement of its organ, the larynx. Yet castration, prior to puberty, has a decided effect upon it; preventing it from becoming raucous and unmelodious. All these developements are synchronous, but not directly consequent upon each other. The generative function has two organs,—one *encephalic*, the other *external;* and it is not surprising, that both of these should undergo their developement at the same period. We shall see hereafter, that Gall offers us reasons for believing, that the *instinct* of propagation has its seat in the cerebellum; and as the most intimate connexion and dependence must exist between the encephalic and the external apparatus, it is not surprising, that the removal of the latter should prevent the developement of the former, and of the instinct of which it is the organ. If, however, the operation of castration be performed after puberty, the instinct is not suppressed, because the necessary developement has already taken place, and the cerebellum is in a condition for fulfilling the function. The continuance of the instinct, under such circumstances, Adelon conceives to be strong evidence against the existence of such internal impressions.

The influence which Cabanis has ascribed to the uterus in females, and to the abdominal organs in the melancholic and hypochondriac, are esteemed to belong to that excited by the temperament, or by the different organs of the body on the brain; which has already fallen under discussion.

On the whole, then, we are perhaps justified in concluding, that the encephalon alone is the organ of the intellectual and moral faculties. The interesting topic of the various instinctive operations of the frame will be considered in another part of this treatise. We shall there find, that instinct cannot well be defined, in the language of Broussais, to consist in sensations originating in the internal and external sensitive surfaces, and which solicit the cerebral centre to acts necessary for the exercise of the functions—such acts being frequently executed without the participation of the mind, and even in its absence—inasmuch as it is not confined to beings possessed of brain, but exists also in the vegetable.

Having now decided upon the organ;—according to the system adopted in this work, it would be necessary to describe its anatomy. But this has been done elsewhere. We pass on, therefore, to the consideration of the

Physiology of the Intellectual and Moral Faculties.

When the organ of the intellect is exposed by accident, and we regard it during the reception of a sensation, the exercise of volition, or during any intellectual or moral operation, the action is found to be too molecular to admit of detection. At times, during violent mental contention, a redness has been apparent, as if the blood were forced more violently into the vessels; but no light has been thrown by such examinations on the wonderful action, which constitutes thought. We ought not, however, to be surprised at this, when we reflect, that the most careful examination of a nerve does not convey to us the slightest notion how an impression is received by it from an external body; and how such impression is conveyed to the brain. All that we witness in these cases is the result; and we are thus compelled to study the intellectual and moral acts by themselves, without considering the cerebral movements concerned in their production. Such study is the basis of a particular science—*metaphysics*, *ideology* or *philosophy*. Apart from organization, this subject does not belong to physiology; but as some of the points of classification, &c. are concerned in questions that will fall under consideration, it may be well to give a short sketch of the chief objects of metaphysical inquiry; which are, indeed, intimately connected in many of their bearings,—as commonly treated of by the metaphysician,—with our subject. Broussais has considered, that metaphysics and physiology should be kept distinct; and that all the investigations of the metaphysician should be confined to the ideal. "I wish metaphysicians, since they so style themselves," he remarks somewhat splenetically, "would never treat of physiology; that they would only occupy themselves with ideas as ideas, and not as modifications of our organs; that they would never speak either of the brain, the nerves, the temperaments, nor of the influence of climates, of localities, or of regimen; that they would never inquire whether there are innate ideas, or whether they come through the medium of the senses; that they would not undertake to follow their developements according to age or state of health; for I am convinced that they cannot reason justly on all these points. Such questions belong to physiologists, who can unite a knowledge of the moral nature with that of the structure of the human body." "It is possible," he adds, "that particular circumstances may oblige them to introduce physiological considerations in their calculations; such are the cases in which it is necessary to estimate the influence of certain laws or customs in relation to temperature, to the nature of the soil, the prevailing diseases, &c. but then they should avail themselves of the experience of physiologists and physicians." A more appropriate recommendation would have been, that the metaphysician should make a point of becoming acquainted with physiological facts and reasoning; and, conversely, that metaphysics should form a part of the study of every physiologist.

The cerebral manifestations comprise two very different kinds of acts;—the *intellectual* and the *moral:* the former being the source of all the knowledge we possess regarding ourselves and the bodies surrounding us: the latter comprising our internal feelings, our appetites, desires, and affections, by which we are excited to establish a relation with the beings around us:—the two sets of acts respectively embracing the *qualities of the mind* and of the *heart.*

If we attend to the different modes in which the intellectual manifestations are evinced in our own persons, we shall find that there are several operations, which differ essentially from each other. We are conscious of the difference between perceiving an impression made upon one of the external senses, which constitutes *perception,* and the recalling of such impression to the mind,—which is the act of *memory;* as well as the distinction between feeling the relations, which connect one thing to another, constituting *judgment;* and the tendency to act in any direction, which we call *will.* The consciousness of these various mental acts has induced philosophers to admit the plurality of the intellectual acts, and to endeavour to reduce them all to certain *primary* faculties; in other words, to faculties, which are fundamental or elementary; and which, by their combination, give rise to other and more complex manifestations. To this analytical method they have been led by the fact, that these different acts, which they have esteemed elementary, exhibit great variety in their degrees of activity; that one, for example, may be impressed with a character of great energy—as the memory—

whilst another, as the judgment, may be singularly feeble,—and conversely.

Broussais, indeed, conceives, that without the memory we cannot exercise a single act of judgment; since it is always necessary, in order to judge, that we should experience two successive perceptions; that is, that we should feel them alternately, which we could not do, unless possessed of the faculty of renewing that, which we felt an instant before; or, in other words, unless we possessed memory. Hence the loss of this faculty, he says, necessarily occasions that of judgment, and reduces man to a state of imbecility.

To a certain extent this is doubtless true. Total privation of memory must be attended with the results described; that is, if the individual has no consciousness of that which has impressed him previously; for it is obvious, that in such a case, there can be no comparison. A man, however, may have an unusual memory for certain things, and not for others; he may astonish us by the extreme accuracy of his recollection of numbers, places, or persons, and yet he may be singularly deficient in judging of ordinary matters; his memory suggesting only one train of objects for comparison.

In enumerating the faculties, which, by their union, constitute the intellect, we observe the greatest discrepancy amongst metaphysicians; some admitting *will*, *imagination*, *understanding* and *sensibility;* others *sensibility*, *imagination*, *memory*, and *reason;* others *will*, *intelligence*, and *memory;* others, again, *imagination*, *reflection*, and *memory*.

The views of Condillac on this subject have perhaps excited more attention than those of any other individual. Professing, as we have seen, that all our ideas are derived from the successive operations of the senses and the mind, he admits the following constituent faculties in the intellect:—*sensation*, *attention*, *comparison*, *judgment*, *reflection*, *imagination*, and *reason*. *Sensation* he defines the faculty of the mind, which affords the perception of any sensitive impression. *Attention*, the faculty of sensation, applied exclusively to a determinate object; being, as the word imports, the tension of the mind upon a particular object. *Comparison*, the faculty of sensation applied to two objects at once. *Judgment*, the faculty by which the mind perceives the connexions, that exist between the objects compared. *Reason*, the faculty of running through a succession of judgments, which are connected with, and deduced from, each other. *Reflection*, as the word indicates, the faculty by which the mind returns upon itself, upon its own products, to prove their correctness, and to subject them again to its power:—and *imagination*, to which Condillac attaches memory, the faculty possessed by the mind of reproducing at will the different impressions, and all the products of its own operations.

With regard to the order of catenation of these different faculties, he considers *sensation* to be first put in play; and if, amongst the perceptions, there is one of which we have a more lively consciousness, and which attracts the mind to it alone, it is the product of *attention;* then comes *comparison*, which is nothing more than a double attention; comparison is irresistibly succeeded by *judgment;* if, from one judgment, we pass to another deduced from it, we *reason;* if the mind turns back on its own products, we *reflect;* and, lastly, if the mind spontaneously awakens its different perceptions, *imagination* is in action. All these faculties are thus made to be deduced from each other; to originate in the first, or in sensation; and all are this first sensation successively transformed.

The doctrine of Condillac, abstractly considered, has already engaged attention. The division of the faculties, which, he conceives, by their aggregation, form the intellect, is simple and ingenious, and appears to be more easily referable to physiological principles than that of other metaphysicians; accordingly, it has been embraced, with more or less modification, by certain physiological writers.

The power of reflection, according to Broussais, is the characteristic of the human intellect; and to reflect is to feel. Man not only feels the stimulation produced by external organs, and by the movements of his own organs, which constitutes *sensation* or *perception*, but he is conscious that he has felt these stimulations; or, in other words, he *feels that he has felt;* he has consequently a perception of his actual perception. This, he says, constitutes mental *reflection.* This process man can repeat as often as he thinks fit, and can observe all his sensations, and the different modes in which he felt, whilst occupied with his feelings. From this study he derives an idea of his own existence. "He distinguishes himself in the midst of creation, and, paying regard only to his own existence, compared with all that is not himself, he pronounces the word *I*, (*moi*,) and says, *I am;* and, viewing himself in action, says, *I act, I do*," &c. Perception of himself and of other bodies procures him what are denominated *ideas*. This is, therefore, another result of reflection; or, in other words, of the faculty he possesses of feeling himself feel; but man feels, besides, that he has already felt—this constitutes *memory*. In comparing two perceptions with each other, which are felt in succession, a third perception results, which is *judgment.* Consequently, to judge is only to feel. Hence, he concludes, "*sensation, reflection*, and *judgment*, are absolutely synonymous, and present to the physiologist nothing more than the same phenomenon. The *will*, or that faculty by virtue of which man manifests his liberty by choosing, among different perceptions, the one he must obey—that faculty, which gives him the power of resisting, to a certain extent, the suggestions of instinct, is founded on reflection. Consequently, when we consider it in a physiological point of view, we can only discover in it the faculty of feeling ourselves, and of perceiving that we feel ourselves."

Some of the later French metaphysicians have proposed certain modifications in the system of Condillac. M. De La Romiguière, for instance, denies that sensation is the original faculty, and he derives all from attention. The mind, he remarks, is passive during the reception of sensation, and does not commence action until directed to some object, or until it *attends*. According to him, the intellect consists of only three faculties—the *attention; comparison*, or double attention; and *reason*, or double comparison. Judgment, imagination, and memory, are not primary faculties: judgment is the irresistible product of comparison; memory is but the trace, which every perception necessarily leaves behind it; and imagination is but a dependence on reason.

M. Destutt-Tracy again, reduces the number of primary faculties to four—*perception, memory, judgment*, and *will* or *desire*. According to him, *attention* is not an elementary faculty. It is but the active exercise of the intellectual faculties. The same applies to *reflection* and *reason*, which are only a judiciously combined employment of those faculties; and to *comparison* and *imagination*, both of which enter into the judgment.

The division of M. Destutt-Tracy is embraced by Magendie in his *Précis Elémentaire de Physiologie.*

Stewart's classification is into, 1. *Intellectual powers*, and, 2. *Active* and *moral powers;* including, in the former, *perception, attention, conception, abstraction*, the *associating principle, memory, imagination*, and *reason*. Brown reduces all the *intellectual states* to *simple suggestion* and *relative suggestion*, comprising, in the former, *conception, memory*, and *imagination*,—in the latter, *judgment, reason, abstraction*, and *taste*. Abercrombie considers the mental operations to be chiefly referable to *four heads;—memory, abstraction, imagination*, and *reason* or *judgment;* whilst Kant has "twenty-five primary faculties or forms; pure conceptions or ideas *a priori.*

These are a few only of the discrepant divisions of psychologists. The list might have been extended by the classifications of Aristotle, Bacon, Hobbes, Locke, Bonnet, Hume, Vauvenargues, Diderot, Reid, and others. Perhaps the most prevalent opinion at present is, that the original faculties are—*perception, memory, judgment*, and *imagination*. It is impossible for us, were it even our province, to reconcile these discrepancies. They are too considerable for us to hope, that this will ever be effected by metaphysical inquiry. We must, therefore, look to physiological investigation, if not with well founded—with the only—hopes, we can entertain, for the elucidation of the subject; and we shall find presently, that the minds of metaphysical physiologists have been turned in this direction, and that many interesting facts and speculations have been the result.

A second topic of metaphysical inquiry regards the formation of the intellectual notions we possess. On this, there have been two principal opinions. Some, as Plato, Descartes, the Kantists, Kantoplatonists, &c. believing in the existence of *innate ideas* of things; —others, as Bacon, Locke, and Condillac, denying the existence of such innate ideas, and asserting, that the human intellect, at birth, is a *tabula rasa*, and that the mind has to acquire and form all the ideas it possesses from impressions made on the senses.

The truth includes probably both these propositions—the action of the senses and of the intellectual faculties being alike necessary; the former receiving the external and internal impressions, and transmitting them to the mind, which, through the cerebral organ, produces the different intellectual acts.

Under the terms *affective faculties*, *affections*, *passions*, are comprehended all those active and moral powers, which connect us to the beings that surround us, and are the incentives of our social and moral conduct. To this class belong the feeling, which attaches the parent to the child; that which draws the sexes together; and the feeling of compassion, by which we are led to assist a suffering fellow-creature. They are, in truth, internal sensations, but of a higher cast than those of hunger and thirst; the latter being purely physical and announcing physical necessities, the former suggesting social and moral relations. Such affective faculties are the foundation of what are called moral wants; and, like the internal sensations in general, are the source of *pleasure*, when satisfied,—of *pain*, when resisted; and it is only when they are extreme and opposed, that they acquire the name of *passions*.*

The analysis of these is attended with the same difficulties as that of the intellectual faculties. Their plurality is universally admitted, but still greater discrepancy exists as to their precise number and connexion.

Many moralists have united the moral faculties under the head of *will* or *desires*. Condillac is one of those. Every sensation, he observes, has the character of pleasure or pain, none being indifferent: as soon, therefore, as a sensation is experienced, the mind is excited to act. This tendency is at first but slightly marked, and is only an uneasiness (*malaise:*) but it soon increases, becomes *restlessness* or *inquietude;* in other words, a difficulty experienced by the mind of remaining in the same situation. This gradually becomes *desire*, *torment*, *passion*, and finally *will*, excited to the execution of some act.

Many moralists have endeavoured, by ultimate analysis, to derive all the affective faculties of the mind, from one principal faculty—that of *self-love*,—the inward feeling, which induces all men to attend to themselves, their own preservation, and welfare. All the faculties, they assert, are returns of this self-love upon itself; and, as in the case of the intellectual faculties, attempts have been made to classify them; but no two scarcely agree. Some have divided them into the *agreeable* and *distressing;* others into those of *love* and *hatred;* many, regarding their effects upon society, into the *virtuous*, *vicious*, and *mixed*. The first comprising those that are useful to society,—as *filial*, *parental*, and *conjugal love*, which

* From *patior*, I suffer.

form the foundation of families; *goodness*, *pity*, and *generosity*, which, by inducing men to assist each other, facilitate the social condition; and the *love of labour*, *honour*, and *justiee;* which have the same result by constituting so many social guaranties. The vicious passions, on the contrary, are such as injure man individually and society in general, as *pride*, *anger*, *hatred*, and *maliee*. Lastly, the mixed passions are such as are useful or injurious, according to their use or abuse; such as *ambition*, which may be a laudable emulation or insatiable passion, according to its extent and direction.

Again, the passions have been divided into the *animal* or such as belong to physical man, and the *soeial* or such as appertain to man in society. The first are guides to him for his own preservation as well as for that of the species. To them belong *fear*, *anger*, *sadness*, *hatred*, *excessive hunger*, the *venereal desires* when vehement, *jealousy*, &c. In the second are included all the social wants, when inordinately experienced. These vary according to the state of civilization of the individual and the community. *Ambition*, for instance, it is said, may be regarded, when inordinate, as excessive love of power:—*avarice*, as an exaggeration of the desire for fortune:—*hatred* and *vengeanee*, as the natural and impetuous desire of injuring those that injure us, &c.

Stewart's division of the *active* and *moral powers* embraces, 1. *Instinetive principles*, and 2. *Rational principles:* the former iucluding *appetites*, *desires*, and *affections*, the latter *self-love* and the *moral faeulty;* all of which Brown comprises under *emotions*, immediate, retrospective, or prospective;—and *lastly*, Abercrombie refers all the principles, which constitute the moral feelings, to the following heads: 1. The *desires*, the *affections* and *self-love;* 2. The *will;* 3. The *moral prineiple*, and 4. The moral relation of man towards the Deity.

It is obvious, that the analysis of the moral faculties has been still less satisfactorily executed than that of the intellectual; and that little or no attempt has been made to specify those that are primary or fundamental, from those that are more complex. The remarks, consequently, which were made regarding the only quarter we have to look to, for any improvement in our knowledge of the intellectual acts, apply *a fortiori* to the moral; although it must be admitted, that the difficulties attendant upon the investigation of the latter are so great as to appear to be almost, if not wholly, insuperable.

As the brain, then, is admitted to be the organ of the intellectual and moral faculties, its structure probably varies according to the number and character of those; and if there be primary or fundamental faculties they may each have a special organ concerned in their production, as each of the external senses has an organ concerned in its production. According to this view, the cerebral organization of animals ought to differ according to their psychology: where one is simple the other should be so likewise.

This seems, so far as we can observe, to be essentially the fact. "In the series of animals," says Adelon, "we observe the brain more complicated as the mental sphere is more extensive; and in this double respect a scale of gradation may be formed from the lowest animals up to man. If he has the most extensive moral sphere, if he alone possesses elevated notions of religion and morality, he has also the largest brain, and one composed of more parts; so that if the physiology of the brain were more advanced, we might be able, by comparing the brains of animals with his, to detect the material condition, which constitutes humanity. If the brain were not constructed, *a priori*, for a certain psychology, as the digestive apparatus is for a certain alimentation, if the mental and moral faculties were not as much innate as the other faculties, there would be nothing absolute in legislation or morals. The brain and its faculties are, however, in each animal species, in a ratio with the *rôle*, which such species is called upon to fulfil in the universe. If man is, in this respect, in the first rank; if he converts into the delicate affections of father, son, husband, and country, those brute instincts, by which the animal is attached to its young, its female, or its kennel; if, in short, he possesses faculties which animals do not,—religious and moral feelings, with all those that constitute humanity,—it is owing to his having a more elevated vocation; to his being not only the king of the universe, but destined also for a future existence, and specially intended to live in society. Hence it was necessary that he should not only have an intellect sufficiently extensive to make all nature more or less subject to him, but also a psychology such, that he might establish social relations with his fellows. It was necessary that he should have notions of the just and unjust, and be able to elevate himself to the knowledge of God;—those sublime feelings, which cause him so to regulate his conduct as to maintain with facility his mortal connexions, and to deserve the future life to which he is called."

But if the intellectual sphere be regulated by the cerebral developement, can we not, it has been asked, estimate the connexion between them? And if there be different primary cerebral faculties, each of which must have an organ concerned in its production, can we not point out such organ in the brain? Several investigations of this character have been attempted, with more or less success: generally, however, they have added but little to our positive knowledge, and this, principally, from the intricacy of the subject.

Until of late years, attention was chiefly paid to the mass and size of the encephalon; and it was, at one time, asserted, that the larger this organ, in any species or individual, the greater the intellect. Man, however, has not absolutely the largest encephalon although he is unquestionably the most intelligent of beings. The weight of the encephalon of a child six years of age is given by Haller at two pounds three ounces and a half; whilst that of the adult is estimated by Sömmering at from two pounds three ounces, to three pounds three ounces and three quarters; and that of the elephant, according to Haller, weighs from seven to ten pounds. This, consequently, overthrows the proposition; and, besides, in certain insects with very minute brains, as the bee and the ant, we meet with evidences of singular intelligence. The proposition was therefore modified, and it was laid down, that the larger the encephalon, compared with the rest of the body, the greater the mental sphere. When the subject was first investigated in this way, the result, in the case of the more common and domestic animals, was considered so satisfactory, that, without farther comparison, the proposition was considered to be established. More modern researches have shown, that it admits of numerous exceptions, and that several of the mammalia, and many diminutive and insignificant animals have the advantage over man in this respect. It has, indeed, been properly observed by Mr. Lawrence, that it cannot be a very satisfactory mode of proceeding to compare the body, of which the weight varies so considerably, according to illness, emaciation, or *embonpoint,* with the brain, which is effected by none of these circumstances, and appears to remain constantly the same. This is the cause, why, in the cat, the weight of the encephalon, compared with that of the body, has been stated as 1 to 156 by one comparative anatomist, and as 1 to 82 by another; that of the dog as 1 to 305 by one, and as one to 47 by another, &c.

The following table, taken chiefly from Haller and Cuvier, exhibits the proportion, which the encephalon bears to the rest of the body, in man and certain animals.

Child, 6 years old	$\frac{1}{22}$	Elephant	$\frac{1}{500}$
Adult	$\frac{1}{35}$	Stag	$\frac{1}{290}$
Gibbon	$\frac{1}{48}$	Roebuck (young)	$\frac{1}{94}$
Sapajous, from	$\frac{1}{41}$ to $\frac{1}{22}$	Sheep	$\frac{1}{351}$ to $\frac{1}{192}$
Apes	$\frac{1}{48}$ to $\frac{1}{24}$	Ox	$\frac{1}{750}$ to $\frac{1}{860}$
Baboons	$\frac{1}{104}$ to $\frac{1}{86}$	Calf	$\frac{1}{219}$
Lemurs	$\frac{1}{84}$ to $\frac{1}{61}$	Horse	$\frac{1}{700}$ to $\frac{1}{400}$
Bat (vespertilio)	$\frac{1}{96}$	Ass	$\frac{1}{154}$
Mole	$\frac{1}{36}$	Dolphin	$\frac{1}{25}$, $\frac{1}{36}$, $\frac{1}{60}$, $\frac{1}{102}$
Bear	$\frac{1}{265}$	Eagle	$\frac{1}{260}$
Hedgehog	$\frac{1}{168}$	Goose	$\frac{1}{360}$
Fox	$\frac{1}{205}$	Cock	$\frac{1}{25}$
Wolf	$\frac{1}{230}$	Canary bird	$\frac{1}{14}$
Beaver	$\frac{1}{290}$	Humming bird	$\frac{1}{11}$
Hare	$\frac{1}{228}$	Turtle	$\frac{1}{5688}$
Rabbit	$\frac{1}{140}$ to $\frac{1}{152}$	Tortoise	$\frac{1}{2240}$
Rat	$\frac{1}{76}$	Frog	$\frac{1}{172}$
Mouse	$\frac{1}{43}$	Shark	$\frac{1}{2496}$
Wild boar	$\frac{1}{672}$	Pike	$\frac{1}{1305}$
Domestic do.	$\frac{1}{512}$ to $\frac{1}{412}$	Carp	$\frac{1}{560}$

Wrisberg and Sömmering proposed another point of comparison,

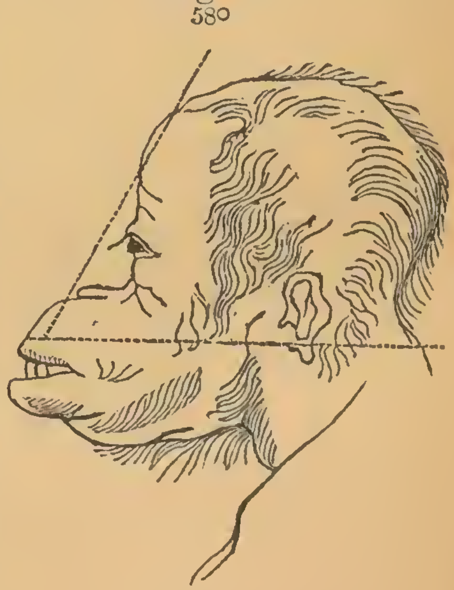
—the ratio of the mass of the encephalon to that of the rest of the nervous system; and they asserted, that, in proportion as any animal possesses a larger share of the former; or, in other words, in proportion as the percipient and intellectual organ exceeds the other or the organ of the external senses—the mental sphere may be expected to be more diversified and developed. But although man is, in general, pre-eminent in this respect, he is not absolutely so. It would be still more important to know the ratio, that the cerebrum or brain proper bears to the cerebellum and medulla oblongata. The first is essentially the organ of intellect; and the most striking character of the human brain is the large developement of the cerebral hemispheres, of which we have no parallel in the animal kingdom. The last is the encephalic part in which all the nerves of the senses arise or terminate.

The assertion, that man has the largest cerebrum in proportion to the cerebellum, is not at all accurate. The Wenzels found the ratio, in man, to be as $6\frac{51}{129}$ or $8\frac{42}{121}$ to 1; in the horse, $4\frac{1}{2}$ to 1; in the cow, $5\frac{173}{211}$ to 1; in the dog, $6\frac{4}{29}$ to 1; in the cat, $4\frac{4}{15}$ to 1; in the mole, $3\frac{2}{3}$ to 1; and in the mouse, $6\frac{2}{3}$ to 1. Nor is it true that man has the largest cerebrum in proportion to the medulla oblongata and medulla spinalis; although to this position there are perhaps fewer objections than to any of the others. None of them, it is obvious, are distinctive between man and animals, or assist us in solving the great problem of the source and seat of the numerous psychological differences we observe in different animals and men. Yet various plans have been devised for appreciating the comparative size of the cranium,—which is in a direct ratio with that of the brain—and of the bones of the face. As the former contains the organ of the intellect, and the latter those of the external senses and of mastication; it has been presumed, that the excess of the former would indicate the predominance of thought over sense; and, conversely, that the greater developement of the face would place the animal lower in the scale.

One of these methods, which was first proposed by Camper, is by taking the course of the *facial line*, and the amount of the *facial angle*. The *facial line* is a line drawn from the projecting part of the forehead to the alveoli of the incisor teeth of the upper jaw; and the facial angle is that formed between this line and another drawn horizontally backwards from the upper jaw. The course of the horizontal line and its point of union with the facial line are not uniform in all the figures given by Camper: sometimes it is made to pass through the meatus auditorius externus, but it often falls far below it; yet Dr. Bostock thinks, "we cannot hesitate to admit the correctness of Camper's observations, and we can scarcely refuse our assent to the conclusion that he deduces from them." In man, whose face is situated perpendicularly under the cranium, the facial angle is very large. In animals, the face is placed in front of the cranium; and, as we descend from man, the angle becomes less and less, until it is finally lost; the cranium and face being, in most reptiles and fish, completely on a level. The marginal figure exhibits the difference between the facial angle of those of European descent, and that of the negro. By covering with the finger the parts below the nose alternately, we have the countenance of the white or of the negro, in which the facial angle differs as much as 10°, or 15°. Figure 51 exhibits the facial line and angle of the ourang-outang. Those animals that have the snout long, and the facial angle consequently small, have been proverbially esteemed foolish,—such as the snipe, stork, crane, &c.; whilst superior intelligence is ascribed to those in which the angle is more largely developed—as the elephant and the owl; although in them, the large facial angle is caused by the size of the frontal sinuses or by the wide separation between the two tables of the skull, and is necessarily no index of the size of the brain. Yet, from this cause, perhaps, the owl was chosen as an emblem of the goddess of wisdom; and the elephant has received a name in the Malay language, indicating an opinion, that he is possessed of reason. The following table exhibits the facial angle in man and certain animals, taken by a line drawn parallel to the floor of the nostrils, and meeting another, drawn from the greatest prominence of the alveoli of the upper jaw to the prominence of the forehead.

Fig. 50.

Fig. 51.



Man	65° to 85° and more.	Pole cat	31°
Sapajou	65°	Pug dog	35°
Ourang-outang	56° or 58°	Mastiff	41°
Guenon	57°	Hare	30°
Mandril	30° to 42°	Ram	30°
Coati	28°	Horse	23°

The facial angle may, then, exhibit the difference between man and animals; and, to a certain extent, between the species or individuals of the latter; but, farther, it is of little or no use.

In man it may be considered to vary from 70° to 85° in the adult, but in children it reaches as high as 90°;—a sufficient proof, that it cannot be regarded as a measure of the intellect. In the European, it is, on the average perhaps, 80°, in the Mongol, 75°, and in the negro, 70°, not many degrees above the ourang-outang. It is found, however, that the skulls of different nations, and of individuals of the same nation, may agree in the facial angle, whilst there may be striking distinctions in the shape of the cranium and face, in the air and character of the whole head, as well as in the particular features; the inclination of the facial line being obviously more dependent on the prominence of the upper jaw and frontal sinuses than on the general form of the head. The ancients had been impressed with the intellectual air exhibited by the open facial angle; for we find in all their statues of legislators, sages, and poets, an angle of at least 90°, and in those of heroes and of superhuman natures it is carried as high as 100°.

This angle, according to Camper, never existed in nature; and yet he conceives it to be the *beau ideal* of the human countenance, and to have been the ancient model of beauty. It was, more probably, the model of superior intellectual endowment, although ideas of beauty might have been connected with it. Every nation forms its notions of beauty, derived from this source, chiefly from the facial angle to which it is accustomed. With the Greeks it was large, and therefore the vertical facial line was highly estimated. For the same reason it is pleasing to us; but such would not be the universal impression. Most savage tribes, on our own continent, have preferred the pyramidal shape of the head, and made use of every endeavour, by unnatural compression in early infancy, to produce it; whilst others, not satisfied with the natural shape of the frontal bone, have forced back the forehead, either by applying a flat piece of board to it, like the Indians of our own continent, or by iron plates, like the inhabitants of Arracan. By this practice, the Caraibs are said to be able to see over their heads.

Daubenton, again, endeavoured, by taking the *occipital line* and *angle*, to measure the differences between the skulls of man and animals. One line is drawn from the posterior margin of the foramen magnum of the occipital bone to the inferior margin of the orbit, and the other from the top of the head to the space between the occipital condyles. In man, these condyles, as well as the foramen magnum, are so situated, that a line drawn perpendicular to them would be a continuation of the spine; but in animals they are placed more or less obliquely: the perpendicular would necessarily be thrown farther forward, and the angle be thus rendered much more acute.* Blumenbach says, that Daubenton's method may be adapted to measure the degrees of comparison betwixt man and brutes, but not the varieties of national character; for he found it different in the skulls of two Turks, and of three Ethiopians.

Blumenbach found the methods of both Camper and Daubenton insufficient to indicate the varieties in the national and individual character. He, accordingly, describes a new method,—which he calls the *norma verticalis*,—in the "*Decas Collectionis suæ craniorum diversarum gentium.*" It consists in selecting two bones, the frontal from those of the cranium, and the superior maxillary from those of the face, and comparing these with each other,—by regarding them vertically,—placing the great convexity of the cranium directly before him, and marking the relative projections of the maxillary bone beyond the arch of the forehead. The Georgian is thus found to be characterized by the great expanse of the upper and outer part of the cranium, which hides the face. In the Ethiopian, the narrow, slanting forehead allows the face to appear, whilst the cheeks and jaws are compressed laterally and elongated in front; and in the Tungoose, the maxillary, malar, and nasal bones are widely expanded on each side; and the two last rise to the same horizontal level with the space between the frontal sinuses—the glabella.

Blumenbach's method, however, only affords us the comparative dimensions of the two bones in one direction. It does not indicate the depth of the maxillary bone or of the os frontis, or their comparative areas. The view thus obtained is therefore partial.

Finding the inapplicability of other methods to the greater part of the animal creation,—to birds, reptiles, and fishes, for example,—Cuvier suggested a comparison between the areas of the face and cranium under the vertical section of the head. The result of his observations is,—that, in the European, the area of the cranium is four times that of the face,—excluding the lower jaw. In the Calmuck, the area of the face is one-tenth greater than in the European; in the negro, one-fifth, and in the Sapajou, one-half. In the Mandril, the two areas are equal; and, in proportion as we descend in the scale of animals, the area of the face gains over that of the cranium; in the hare, it is one-third greater; in the ruminant animals double; in the horse, quadruple, &c.; so that the intelligence

* By some writers, Daubenton's method is said to consist of "a line drawn from the posterior margin of the occipital foramen to the inferior margin of the orbit; and another drawn horizontally through the condyles of the occipital bone." It is obvious, that no comparative judgment of the cranium and face could be formed from this.

of the animal is said to be greater or less, as the preponderance of the area of the face over that of the skull diminishes or increases.

The truth, according to Sir Charles Bell, is, that the great difference between the bones of the cranium and face in the European and negro is in the size of the jaw bones. In the negro, these were found to bear a much greater proportion to the head and to the other bones of the face than those of the European skull; and the apparent size of the bones of the negro face was discovered to proceed solely from the size and shape of the jaw bones, whilst the upper bones of the face, and, indeed, all that had not relation to the teeth and to mastication, were less than those of the European skull.

Other methods, of a similar kind, have been proposed by naturalists, but they are all insufficient to enable us to arrive at an accurate comparison. Blumenbach asserts, that he found the facial and occipital angles nearly alike in three-fourths of known animals. Moreover, it by no means follows, that, in the same species, there should be a correspondence between the size of the cranium and face. In the European, the face may be unusually large; and yet the mental endowments may be brilliant. Leo the Xth, and Montaigne and Leibnitz, Racine, Haller and Franklin, had all large features. All the methods, again, are confined to the estimation of the size of the whole encephalon; whereas we have seen, that the brain alone is concerned in the intellectual and moral manifestations; although Gall includes, also, the cerebellum. It has already been remarked, that no animal equals man in the developement of the cerebral hemispheres. In the ape, they are less prominent; and below it in the scale of creation, they become less and less; the middle lobes are less arched downwards; and the posterior lobes are ultimately wanting, leaving the cerebellum uncovered; the convolutions are less and less numerous and deep, and the brain at length is found entirely smooth. The experiments of Rolando of Turin, and of Flourens of Paris, are likewise confirmatory of this function of the brain proper. These gentlemen experimented upon different portions of the encephalon, with the view of detecting their functions; endeavouring, as much as possible, not to implicate any part except the one which was the subject of investigation; and they found, that if the cerebral hemispheres were alone removed, the animal was thrown into a state of stupor or lethargy; was insensible to all impressions; was to every appearance asleep, and evidently devoid of all intellectual and affective faculties. On the other hand, when other parts of the encephalon were mutilated,—the cerebellum, for example,—leaving the cerebral hemispheres uninjured, the animal was deprived of some other faculties,—that of moving, for instance,—but retained its consciousness, and the exercise of all its senses.

M. Desmoulins, in his observations on the nervous system of vertebrated animals, is in favour of a view, originally suggested by M. Magendie, that the intellectual sphere of man and animals depends exclusively on the cerebral convolutions; and that examination of the convolutions will point out the intellectual differences, not only between different species, but between individuals of the same species.

According to him, the cerebral convolutions are numerous in animals in proportion to their intelligence; and, in animals of similar habitudes, have a similar arrangement. In the same species, they differ sensibly, according to the degree in which the individuals possess the qualities of their nature:—for example, they vary in the fœtus and in the adult; are manifestly less numerous and smaller in the idiot, and become effaced in protracted cases of insanity. He farther remarks, that the morbid conditions of the encephalon, which occasion mental aberration, are especially such as act upon the convolutions; and that, whilst apoplectic extravasation into the centre of the organ induces paralysis of sensation and motion, the least inflammation of the arachnoid membrane causes delirium. Hence he deduces the general principle, that the number and perfection of the intellectual faculties are in proportion to the extent of the cerebral surfaces.

This view of M. Desmoulins, so far as regards the seat of the intellectual and moral faculties, accords with one to which attention must now be directed, and which has given rise to more philosophical inquiry, laborious investigation, and, it must be admitted, to more idle enthusiasm and intolerant opposition, than any of the psychological doctrines advanced in modern times:—we allude to the views of Dr. Gall on the functions of the brain.

These, as expressed in his large work, *Sur les fonctions du Cerveau et sur celles de chacune de ses Parties*, are, 1st, That the intellectual and moral faculties are innate. 2dly, That their exercise or manifestation is dependent upon organization. 3dly, That the brain is the organ of all the appetites, feelings and faculties; and, 4thly, That the brain is composed of as many particular organs as there are appetites, feelings and faculties, differing essentially from each other.

The importance of Gall's propositions; the strictly physiological direction which they have taken,—the only one, as we have said, which appears likely to aid us in our farther acquaintance with the psychology of man,—require that the physiological student should have them placed before him as they emanated from the author. The work of Gall, however, on the functions of the brain, comprises six octavo volumes, not distinguished for unusual method or clearness of exposition. Fortunately, the distinguished physiologist, Adelon, to whom we have so frequently referred, has spared us the necessity of a tedious and difficult analysis, by the excellent and impartial view which he has given in the *Dictionnaire de Médecine*, and which has been since transferred to his *Physiologie de l'Homme*; both being abridgments of the *Analyse d'un cours du Dr. Gall*, published by him in 1808.

The foundation of this doctrine is, that the brain is not a single organ, but is composed of as many nervous systems as there are primary and original faculties of the mind. In the view of Gall, the brain is a group of several organs, each of which is concerned in the production of a special moral act; and, according as the brain of an animal contains a greater or less number of these organs, and of a greater or less degree of developement, the animal has, in its moral sphere, a greater or less number of, or more or less active, faculties.

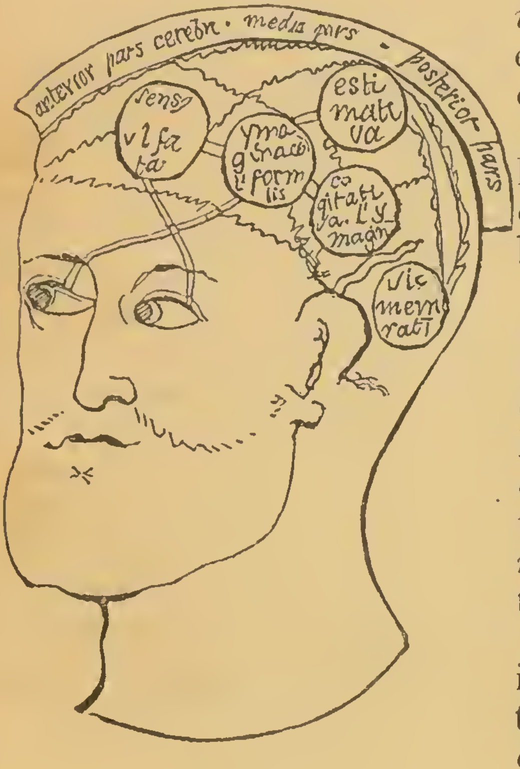
In like manner, as there are as many sensorial nervous systems and organs of sense as there are external senses, there are as many cerebral nervous systems as there are special moral faculties or internal senses. Each moral faculty has, in the brain, a nervous part, concerned in its production, as each sense has its special nervous system; the sole difference being, that the nervous systems of the senses are separate and distinct, whilst those of the brain are crowded together in the small cavity of the cranium, and appear to form but one mass.

The proofs, adduced by Gall in favour of his proposition, are the following:—1st, It has been established as a principle, that the differences in the psychology of man and animals correspond to varieties in the structure of the encephalon, and that the latter are dependent on the former. Now, the differences of the brain consist less in changes of the general form of the organ than in parts, which are present in some and not in others: and if the presence or absence of such parts is the cause, why certain animals have a greater or less number of faculties than others, they ought certainly to be esteemed the special organs of such faculties. 2dly, The intellectual and moral faculties are multiple. This every one admits. Each, consequently, ought to have its special organ; and the admission of a plurality of intellectual and moral faculties must induce that of a plurality of cerebral organs, in the same manner as each external sense has its proper nervous system. 3dly, In different individuals of the same species,—in different men,—much psychological variety is observable. The cause of this is doubtless in the brain; but we can hardly ascribe it to a difference in the general shape of the organ, the form of which is sensibly the same. It is owing rather to differences in the separate parts of the brain. Are not such parts, therefore, distinct nervous systems? 4thly, In the same individual—in the same man—the intellectual and affective faculties have never the same degree of activity; whilst one predominates, another may be feeble. Now, this fact, which is inexplicable under the hypothesis, that the brain is a single organ, is readily intelligible under the theory of the plurality of organs. Whilst the cerebral part, which is the agent of the one faculty, is proportionably more voluminous or more active, that which presides over the other is less so. Why, he asks, may not this happen with the cerebral organs, as with the other organs of the body—the senses, for example? Cannot one of these be feeble and the other energetic? 5thly, In the same individual, all the faculties do not appear, nor are they all lost at the same periods. Each age has its own psychology. How can we, then, explain these intellectual and moral varieties according to age, under the hypothesis, that the brain is a single organ? Under the doctrine of the plurality of cerebral organs, the explanation is simple. Each cerebral system has its special period of developement and decay. 6thly, It is a common observation that when we are fatigued by one kind of mental occupation, we have recourse to another; yet it often happens, that the new labour, instead of adding to the fatigue experienced by the former, is a relaxation. This would not be the case, if the brain were a single organ and acted as such, but it is readily explicable under the doctrine of plurality of organs. It is owing to a fresh cerebral organ having been put in action. 7thly, Insanity is frequently confined to one single train of ideas, as in the variety, called *monomania*, which is often caused by the constancy and tenacity of an original exclusive idea. This is frequently removed by exiting another idea opposed to the first, and which distracts the attention from it. Is it possible, Gall asks, to comprehend these facts under the hypothesis of the unity of the brain? 8thly, Idiocy and dementia are often only partial; and it is not easy to conceive, under the idea of unity of the brain, how one faculty remains amidst the abolition of all the others. 9thly, A wound or a physical injury of the brain will frequently modify but one faculty, paralyzing or augmenting it, and leaving every other uninjured. 10thly, and lastly, Gall invokes the analogy of other nervous parts; and, as the great sympathetic, the medulla oblongata, and medulla spinalis are—in his view at least—groups of special nervous systems, it is probably, he says, the same with the brain.

Such are the arguments employed by Gall for proving, that the brain consists of a plurality of organs, each of which is concerned in the production of a special intellectual or moral faculty, and should they not carry conviction, it must be admitted, that many of them are ingenious and forcible, and all merit attention.

It is a prevalent idea, that this notion of a plurality of organs is a phantasy, which originated with Gall. Nothing is more erroneous: he has adduced the opinions of numerous writers who preceded him, some of whom have given figures of the cranium, with the seat of the different organs and faculties marked upon it. To this list we might add numerous others. Aristotle, in whose works we find the germs of many discoveries and speculations, thought that the first or anterior ventricle of the brain, was the ventricle of *common sense;* because from it, according to him, the nerves of the five senses branched off. The second ventricle, connected by a minute opening with the first, he fixed upon as the seat of *imagination*, *judgment*, and *reflection;* and the third ventricle, as a store-house into which the conceptions of the mind, digested in the second ventricle, were transmitted for retention and accumulation; in other words, he regarded it as the seat of *memory.* Bernard Gordon, in a work written in 1296, gives nearly the same account of the brain. It contains, he says, three cells or ventricles. In the anterior part of the first ventricle lies *common sense;* the function of which is to take cognizance of the various forms and images, received by the several senses. In the posterior part of the first ventricle, he places *phantasia:* and in the anterior part of the second, *imaginativa:* in the posterior part of the middle ventricle lies *estimativa.* It would be a waste of time and space, to adduce the absurd notions, entertained by Gordon on this subject. He thinks there are three faculties or virtues,—*imaginatio, cogitatio,* and *memoria,*—each of which has a special organ engaged in its production.

Fig. 52.

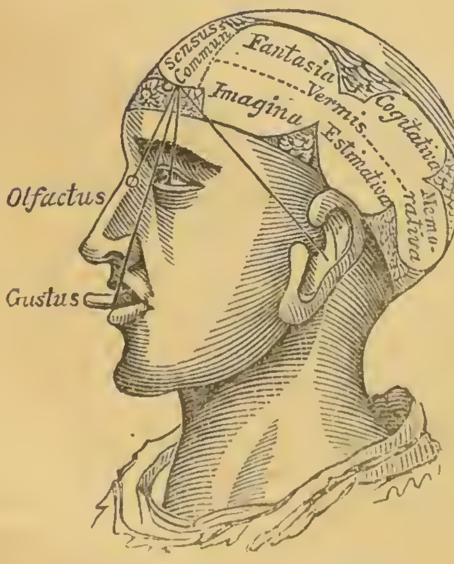


For many centuries it was believed, that the cerebrum was the organ of *perception,* and the cerebellum that of *memory.*

Albert the Great, in the thirteenth century, sketched a head on which he represented the seat of the different intellectual faculties. In the forehead and first ventricle he placed *common sense* and *imagination:* in the second, *intelligence* and *judgment:* and in the third, *memory* and the *motive force.*

The head in the margin (Fig. 52) is from an old sketch contained in the *Book Rarities,* of the University of Cambridge.

Fig. 53.



Head by Dolci, A. D. 1562.

Servetus conceived that the two anterior cerebral cavities are for the reception of the images of external objects; the third is the seat of thought; the aqueduct of Sylvius, the seat of the soul, and the fourth ventricle that of memory.

In 1491, Peter Montagnana published an engraving, in which were represented the seat of the *sensus communis,* a *cellula imaginativa, cellula estimativa seu cogitativa,* a *cellula memorativa,* and a *cellula rationalis.* A head, by Ludovico Dolci exhibits a similar arrangement. (Fig. 53.)

The celebrated Dr. Thomas Willis, in 1681, asserted, that the corpora striata are the seat of perception; the medullary part of the brain that of *memory* and *imagination:* the corpus callosum that of *reflection:* and the cerebellum, according to him, furnished the vital spirits necessary for the involuntary motions.

These examples are sufficient to show, that the attempt to assign faculties to different parts of the brain, and, consequently, the belief, that the brain consists of a plurality of organs, had been long indulged by anatomists and philosophers. The views of Gall are resuscitations of the old; but resembling them little more than in idea. Those of the older philosophers were the merest phantasies, unsupported by the slightest observation; the speculations of the modern physiologist have certainly been the result of long and careful investigation, and of the deepest meditation. Whilst, therefore, we may justly discard the former, the latter are worthy of rigid and unprejudiced examination.

Admitting, with Gall, the idea of the plurality of organs in the brain, the inquiry would next be,—how many special nervous systems are there in the human brain, and what are the primary intellectual and moral faculties over which they preside? This Gall has attempted. To attain this double object, he had two courses to adopt; either, first of all, to indicate anatomically the nervous systems that constitute the brain, and then to trace the faculties of which they are the agents; or, on the contrary, to first point out the primary faculties, and afterwards to assign to each an organ or particular seat in the brain. The first course was impracticable. The cerebral organs are not distinct, isolated in the brain; and, if they were, simple inspection could not inform us of the faculty over which they preside; any more than the appearance of a nerve of sense could exhibit the kind of sensation for which it is destined. It was, only, therefore, by observing the faculties, that he could arrive at a specification of the cerebral organs. But here, again, a source of difficulty arose. How many primary intellectual and moral faculties are there in man? and, what are they? The classifications of the mental philosophers, differing, as we have seen they do, so intrinsically and essentially from each other, could lead him to no conclusion. He first, however, followed the notions on which they appeared to be in accordance; and endeavoured to find particular organs for the faculties of *memory, judgment, imagination,* &c. But his researches in this direction were fruitless. He, therefore, took for his guidance the common notions of mankind; and having regard to the favourite occupations, and the different vocations of individuals, to those marked dispositions, which give occasion to the remark, that a man is born a *poet, musician,* or *mathematician,* he carefully examined the heads of such as presented these predominant qualities, and endeavoured to discover in them such parts of the brain as were more prominent than usual, and which might be considered as special nervous systems,—the organs of these faculties. After multitudinous empirical researches on living individuals; on a collection of crania, and on casts made for the purpose, attending particularly to the heads of such as had one of their faculties predominant, and who were, as he remarks, *geniuses* on one point,—to the maniac, and the monomaniac;—after a sedulous study, likewise, of the heads of animals, comparing especially those, that have a particular faculty, with such as have it not—in order to see if there did not exist in the brain of the former some part which was wanting in that of the latter; by this entirely experimental method, he ventured to specify, in the brains of animals and man, a certain number of organs; and, in their psychology, as many faculties, truly primary in their character.

But, in order, that such a mode of investigation be applicable, it must be admitted, 1st. That one of the elements of the activity of a function is the developement of its organ. 2dly. That the cerebral organs end, and are distinct, at the surface of the brain. 3dly. That the cranium is moulded to the brain, and is a faithful index of its shape; for it is, of course, through the skull and the integuments covering it, that Gall attempts, in the living subject, to appreciate the state of the brain.—Now, within certain limits, these positions are true. In the first place, we judge of the activity of a function, by the size of the organ that executes it: the greater the olfactory nerve, the more acute we find the sense of smell. In the second place, according to the anatomical theory of Gall, the cerebral convolutions are the final expansions of the cerebrum: if we trace back the original fasciculi, which, by their expansions, form the hemispheres of the brain; they are observed to gradually increase in size in their progress towards the circumference of the organ, and to terminate in the convolutions. Lastly, to a certain extent, the cranium is moulded to the brain; and participates in all the changes, which the latter undergoes, at different periods of life, and in disease. For example, during the first days after the formation of the brain in the fœtus, the cranium is membranous, and has exactly the shape of the viscus. On this membrane, ossific points are deposited, so that, when the membrane has become bone, the cranium has still the shape of the brain. In short, nature, having made the skull to contain the brain, has fitted the one to the other; and this so accurately, that its internal surface exhibits sinuosities, corresponding to the vessels that creep on the surface of the brain; and digitations, corresponding to the cerebral convolutions. The brain, in fact, rigidly regulates the ossification of the cranium; and when, in the progress of life, the brain augments, the capacity of the cranium is augmented likewise; not by the effect of mechanical pressure, but owing to the two parts being catenated in their increase and nutrition. This remark applies not only to the skull and brain, regarded as a whole, but to their separate parts. Certain portions of the brain are not developed simultaneously with the rest of the organ; and the same thing happens to the portions of the skull that invest them. The forehead, for example, begins to be developed after the age of four months: but the inferior occipital fossæ do not increase in proportion until the period of puberty.

When the brain, again, fades and wastes in advanced life, the cavity of the cranium contracts, and its ossification takes place on a less and less outline. In advanced life, however, according to Gall, the correspondence between the brain and the inner table of the skull is alone maintained; the outer table appearing to be a stranger to all nutritive movement, and preserving its dimensions. Lastly, the cranium partakes of all the variations experienced by the brain in disease. If the brain be wanting, as in the acephalous monster, the cranium is wanting also. If a portion of the brain exist, the corresponding portion of the cranium exists. If the brain be smaller than natural, as in the idiot, the cranium is so likewise. If the brain, on the contrary, be distended by hydrocephalus, the cranium has a considerable capacity; and this, not owing to a separation, at the sutures, of the bones composing it, but owing to ossification taking place on a larger outline. If the brain be much developed in any one part, and not in another, the cranium is protuberant in the former; restricted in the latter. Lastly, in cases of mania, the cranium is often affected; seeming, for example, to be unusually thick, dense, and heavy.

These reasons, adduced by Gall, may justify the admission, that, within certain limits, the skull is moulded to the brain; and, if we admit this, the method, followed by him, of specifying the organs of the mental faculties, may be conceived practicable.

Such is the basis of the system of *craniology*, proposed by Gall. It also bears the name *cranology*, *organology*, *phrenology*, and *cranioscopy:* though, strictly speaking, it is by *cranioscopy* that we acquire a knowledge of *craniology;* the art of prejudging the intellectual and moral aptitudes of man and animals, from an examination of the cranium. It is, of course, limited in its application. Gall admits, that it is not available in old age; owing to the physiological fact before stated;—that the external table of the skull is no longer modified by the changes, that happen to the brain; and he acknowledges, that its employment is always difficult, and liable to numerous errors. We cannot, in fact, touch the cranium directly, for it is covered by hair and integument. The skull is, likewise, made rough, in particular parts, by muscular impressions; which must not be confounded with what are termed *protuberances;* in other words, with the prominences, that are formed by a corresponding developement of the brain. In this respect, craniology presents more difficulties in animals, from their heads being more covered with muscles, and from the inner table of the skull being, alone, in a ratio with the brain beneath. Other errors may be indulged from the existence of the frontal sinuses, of the superior longitudinal sinus, and from the possible separation of the hemispheres at the median line. The difficulty is, of course, extremely great in appreciating the parts of the brain, that are situated behind the eyes; and craniology must be entirely inapplicable to those organs of the brain, that do not terminate at the surface.

Gall has taken especial pains to remark, that by craniology we can only prejudge the dispositions of men, not their actions; and that we can appreciate but one of the elements of the activity of the organs—their size—not what belongs to their intrinsic activity, and to the impulse or spring they may receive from the temperament, or general formation. Setting out, however, from the principle, that the predominance of a faculty is in a great measure dependent on the developement of the portion of the brain which is its organ, he goes so far as to particularize, in this developement, what is owing to the length of the cerebral fibres, and what to their breadth; referring the activity of the faculty to the former circumstance, and its intensity to the latter.

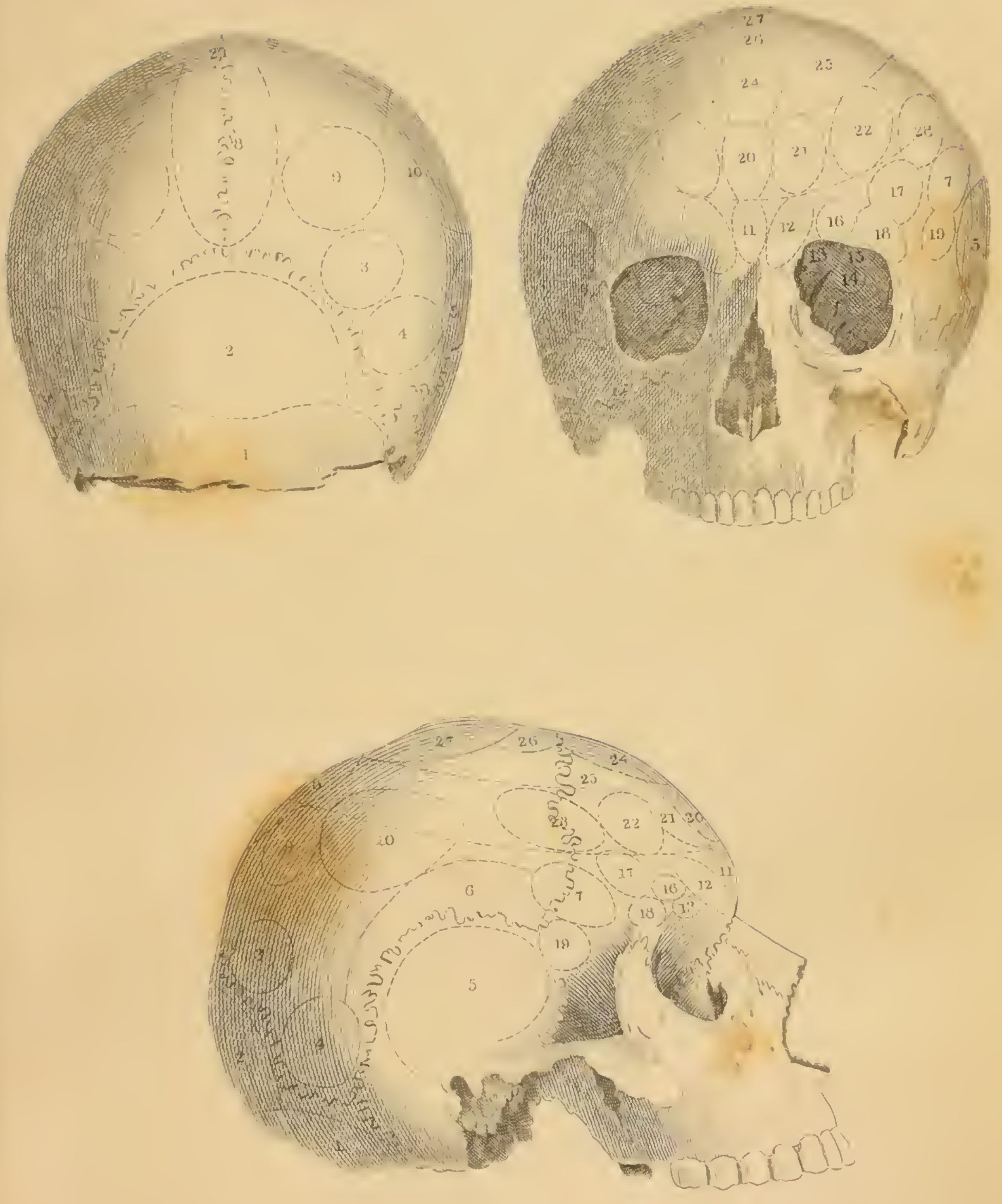
In applying cranioscopy to animals, he observes, that the same cerebral organ frequently occupies parts of the head, which seem to be very different, on account of the difference between *station* in animals and man, and of the greater or less number of systems, that compose their brain.

The cerebral organs, enumerated by Gall, with the corresponding faculties, are as follows;—the numbers, corresponding with those of the accompanying engravings.

1. *Instinct of generation, of reproduction; amativeness. Instinct of propagation; venereal instinct.* (*German.*) Zeugungstrieb, Fortpflanzungstrieb, Geschlechtstrieb.	Seated in the cerebellum. It is manifested at the surface of the cranium by two round protuberances, one on each side of the nape of the neck.
2. *Love of progeny; philo-progenitiveness.* (*G.*) Jungenliebe, Kinderliebe.	Indicated at the external occipital protuberance.
3. *Attachment, friendship.* (*G.*) Freundschaftsinn.	About the middle of the posterior margin of the parietal bone; anterior to the last.
4. *Instinct of defending self and property; love of strife and combat; combativeness; courage.* (*G.*) Muth, Raufsinn. Zanksinn.	Seated a little above the ears; in front of the last, and towards the mastoid angle of the parietal bone.
5. *Carnivorous instinct; inclination to murder; destructiveness; cruelty.* (*G.*) Wurgsinn, Mordsinn.	Greatly developed in all the carnivorous animals; forms a prominence at the posterior and superior part of the squamous surface of the temporal bone, above the mastoid process.

CRANIOLOGICAL DIVISION of GALL

Page 284



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6. *Cunning; finesse; address; secretiveness.* (G.) List, Schlauheit, Klugheit.	Above the meatus auditorius externus, upon the sphenoidal angle of the parietal bones.
7. *Desire of property; provident instinct; cupidity; inclination to robbery; acquisitiveness.* (G.) Eigenthumssinn, Hang zu stehlen, Einsammlungssinn, Diebsinn.	Anterior to that of cunning, of which it seems to be a prolongation, and above that of mechanics, with which it contributes to widen the cranium, by the projection, which they form at the side of the frontal bone.
8. *Pride; haughtiness; love of authority; elevation.* (G.) Stolz, Hochmuth, Höhensinn, Herrschsucht.	Behind the top of the head, at the extremity of the sagittal suture, and on the parietal bones.
9. *Vanity; ambition; love of glory.* (G.) Eitelkeit, Ruhmsucht, Ehrgeiz.	Situated at the side of the last, near the posterior internal angle of the parietal bones.
10. *Circumspection; foresight.* (G.) Behutsamkeit, Vorsicht, Vorsichtigkeit.	Corresponds to the parietal protuberances.
11. *Memory of things; memory of facts; sense of things; educability; perfectibility; docility.* (G.) Sachgedächtniss, Erziehungsfähigkeit, Sachsinn.	Situated at the root of the nose, between the two eyebrows, and a little above them.
12. *Sense of locality; sense of the relation of space; memory of places.* (G.) Ortsinn, Raumsinn.	Answers to the frontal sinuses, and is indicated externally by two prominences at the inner edge of the eyebrows, near the root of the nose, and outside the organ of memory of things.
13. *Memory of persons; sense of persons.* (G.) Personensinn.	At the inner angle of the orbit.
14. *Sense of words; sense of names; verbal memory.* (G.) Wortgedächtniss, Namensinn.	Situated at the posterior part of the base of the two anterior lobes of the brain, on the frontal part of the bottom of the orbit, so as to make the eye prominent.

15. *Sense of spoken language; talent of philology; study of languages.* (G.) Sprachforschungssinn, Wortsinn, Sprachsinn.	Also at the top of the orbit, between the preceding and that of the knowledge of colour.
16. *Sense of the relations of colour; talent of painting.* (G.) Farbensinn.	The middle part of the eyebrows; encroaching a little on the forehead.
17. *Sense of the relations of tones; musical talent.* (G,) Tonsinn.	A little above and to one side of the last; above the outer third of the orbitar arch.
18. *Sense of the relations of numbers; mathematics.* (G.) Zahlensinn.	On the outside of the organ of the sense of the relations of colour, and below the last.
19. *Sense of mechanics; sense of construction; talent of architecture; industry.* (G.) Kunstsinn, Bausinn.	A round protuberance at the lateral base of the frontal bone, towards the temple, and behind the organs of music and numbers.
20. *Comparative sagacity.* (G.) Vergleichender Scharfsinn.	At the middle and anterior part of the frontal bone, above that of the memory of things.
21. *Metaphysical penetration; depth of mind.* (G.) Metaphysischer Tiefsinn.	In part, confounded with the preceding. Indicated, at the outer side of this last, by two protuberances, which give to the forehead a peculiar hemispherical shape.
22. *Wit.* (G.) Witz.	At the lateral and outer part of the last; and giving greater width to the frontal prominences.
23. *Poetical talent.* (G.) Dichtergeist.	On the outer side of the last; divided into two halves by the coronal suture.
24. *Goodness; benevolence; mildness; compassion; sensibility; moral sense; conscience; bonhommie.* (G.) Gutmüthigkeit, Mitleiden, moralischer Sinn, Gewissen.	Indicated by an oblong prominence above the organ of comparative sagacity; almost at the frontal suture.
25. *Imitation; mimicry.* (G.) Nachahmungssinn.	At the outer side of the last.
26. *God and religion; theosophy.* (G.) Theosophisches Sinn.	At the top of the frontal bone and at the superior angles of the parietal bones.

27. *Firmness; constancy; perseverance; obstinacy.* (*G.*) Stetigkeit, Fester Sinn.	The top of the head; at the anterior and most elevated part of the parietal bones.

The first nineteen of these, according to Gall, are common to man and animals; the remaining eight man possesses exclusivèly. They are, consequently, the attributes of humanity.

Spurzheim, a fellow labourer with Gall, who accompanied him in his travels, and was associated with him in many of his publications, has added some other faculties, so as to make the whole number thirty-five; but they have not been embraced by Gall in his most recent publication, whence many of these details are taken. The following are the organs admitted by Spurzheim:—the numbers correspond with those of the accompanying figures.

Fig. 54.

Fig. 55.

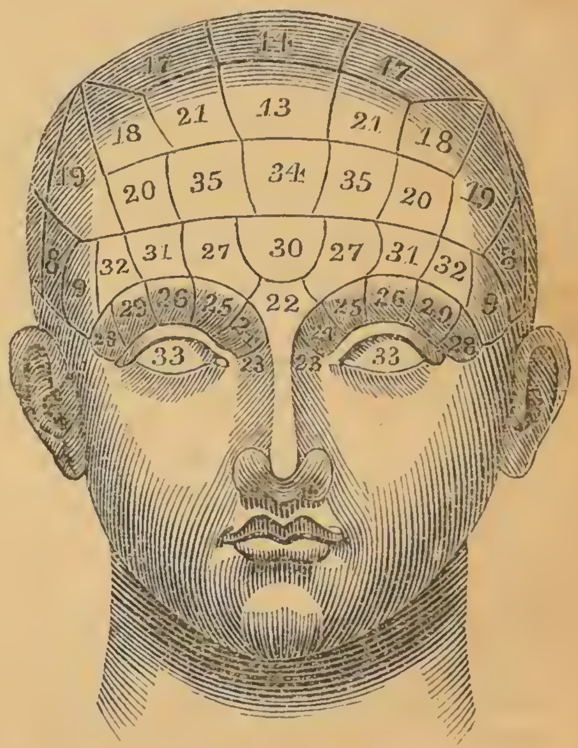
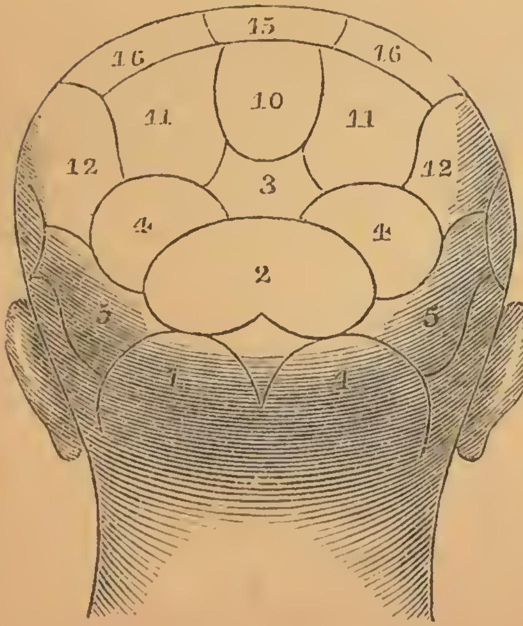


Fig. 56.



ORGAN OF

1. Amativeness.
2. Philoprogenitiveness.
3. Inhabitiveness.
4. Adhesiveness or Attachment.
5. Combativeness.
6. Destructiveness.
7. Constructiveness.
8. Acquisitiveness.
9. Secretiveness.
10. Self-esteem.
11. Love of Approbation.
12. Cautiousness.
13. Benevolence.
14. Veneration.
15. Firmness.
16. Conscientiousness or Justice.
17. Hope.
18. Marvellousness.
19. Wit.
20. Ideality.
21. Imitation.
22. Individuality.
23. Form.
24. Size.
25. Weight and Resistance.
26. Colour.
27. Locality.
28. Numeration.
29. Order.
30. Eventuality.
31. Time.
32. Melody or Tune.
33. Language.
34. Comparison.
35. Causality.

On the situation of the different cerebral organs, Gall remarks,—1st. That those which are common to man and animals are seated in parts of the brain that are common to both:—at the posterior inferior, and anterior inferior, portions. On the contrary, those, that are exclusive to man, are situated in parts of the brain, which exist only in him:—in the anterior superior parts, which form the forehead. 2dly. The more indispensable a faculty, and the more important to the animal economy, the nearer is its organ to the median line and to the base of the brain. 3dly, and lastly. The organs of the faculties, that aid, or are similar to each other, are generally situated in proximity.

In his exposition of each of these organs, and of the reasons, that induce him to assign it as the seat of a special faculty, he sets out by demonstrating the necessity of the faculty, which he regards to be fundamental and primary, and to which he assigns a special nervous system or organ in the brain. 2dly. He endeavours to show, that this faculty is really primary. He considers it to be such, whenever psychological facts show, that it has its exclusive source in organization; for example, when it is not common to all animals and sexes; when, in the individual possessing it, it does not exhibit itself in a ratio with the other faculties with which he is endowed; when it has its distinct periods of developement and decrease, and does not, in this respect, coincide with the other faculties; when it can be exerted alone, be diseased alone, continue sound alone, or be transmitted alone from parent to child, &c. Lastly, he points out the part of the brain, which he considers to be its organ, founding his decision on numerous empirical observations of the brains of men and animals, that have possessed, or been devoid of, the faculty and organ in question; or have had them in unequal degrees of developement.

It is impossible for us, in a work of this kind, to exhibit all the views of Gall, and the arguments he has adduced in favour of the existence of his twenty-seven faculties. The selection of one—the *instinct of generation*—will be sufficient to show how he treats of the whole.

Gall's *instinct of generation* is that, which, in each animal species, impels the individuals of different sexes towards each other for the purpose of effecting the work of reproduction. The *necessity* of such an inclination for the general preservation of animals is manifest. It is to the preservation of the species what the sensation of hunger is to that of the individual. Again, it is certainly *primary* and *fundamental*, for it is independent of all external influence. It does not make its appearance until puberty, and it disappears long before other faculties. In many animals it returns periodically. In each animal species, and in each individual, it has a special and different degree of energy; although external circumstances may be much the same in all, or at least may not present differences, in any manner proportionate to those of the instinct. It may be either alone active, amidst the languor of other faculties, or it may be alone languishing. Lastly, it cannot be referred to the genital organs, for it has been observed in children, whose organs have not been developed; it has frequently continued to be felt in eunuchs; and has been experienced by females, who, owing to original monstrosity, have had neither ovary nor uterus (?)

The part of the brain which is the *organ* of this instinct, is, according to Gall, the *cerebellum*. His reasons for this belief are the following. 1st. In the series of animals a cerebellum exists only in those, which are reproduced by copulation, and which, consequently, must have the instinct in question. 2dly. There is a perfect coincidence between the periods at which the cerebellum becomes developed, and the appetite appears. In infancy, it does not exist, and the organ is therefore small. 3dly. In every species of animal and in every individual, there is a ratio between the size of the cerebellum and the energy of the inclination. In males, in whom it is generally more imperious, the cerebellum is always larger. 4thly. A ratio exists between the structure of the cerebellum and the kind of generation. In oviparous animals, for instance, the cerebellum is smaller at its median part; and it is only in the viviparous, that the hemispheres exist. 5thly. A similar ratio exists between the cerebellum and the external genital organs. If the latter are extirpated at an early age, the developement of the cerebellum is arrested, and it continues small for the remainder of life. Neighbouring parts, too, which are attributes of the male sex, as the horns of the stag, and the crest of the cock, are often similarly stunted. On the other hand, the cerebellum, in its turn, exerts a close influence on the venereal appetite, and modifies the external genital organs. Injuries of the cerebellum either render the individual impotent, or excite an erotic mania. In nymphomania, the patient often complains of acute pain in the nape of the neck; and this part is more tumid and hot in animals at the rutting season. Gall asserts, that he has noticed in birds, that the cerebellum differs both in size and excitation, during the season of love, from what it is at other times; and he affirms, that if erection is observed in those, who are hanged, or in consequence of the application of a blister or a seton to the nape of the neck, or of the use of opium, or, who are threatened with apoplexy, especially when the apoplexy is cerebellous, or, during sleep, the effect is, in all these cases, owing to congestion of blood in the brain in general, and in the cerebellum in particular. From these data, Gall concludes, that the cerebellum is the organ of the instinct of reproduction; and he remarks, that as this organ presides over one of the most important faculties, it is situated on the median line; and at the base of the skull.—In this manner, he proceeds, with more or less success, in his investigation of other cerebral organs and faculties.

But Gall does not restrict himself to the physiological applications of his system. He endeavours, likewise, to explain the differences, that exist between him and other philosophers. He altogether rejects the primary faculties of *instinct, intelligence, will, liberty, reason, perception, memory, judgment,* &c. of the metaphysician, as mere generalizations of the mind, or common attributes of the true primary faculties. Whilst, in the study of physics, the general and special qualities of matter have been carefully distinguished, and the latter have been regarded as alone founding the particular nature of bodies; the metaphysician, says Gall, has restricted himself to general qualities. For example, it is asserted, that "to *think* is to *feel.*" Thought is doubtless a phenomenon of sensibility; but it is a sensitive act of a certain kind. To adhere rigidly to this expression, says Gall, is but to express a generality, which leaves us in as much ignorance as to what is thought, as we should be of a quadruped or bird, by saying that it is an animal; and as, to become acquainted with such animals, their qualities must be specified, so to understand thought, the kind of sensation must be specified, that constitutes it. *Instinct,* according to him, is a general expression, denoting every kind of internal impulse; and consequently there must be as many instincts as there are fundamental faculties. *Intelligence* is likewise a general expression, designating the faculty of knowledge; and, as there are many instincts, so are there many kinds of intelligence. Philosophers, he thinks, have erroneously ascribed instinct to animals, and intelligence to man. All animals have, to a certain extent, intelligence; and in man many faculties are instincts. Neither is the *will* a fundamental faculty. It is only a judgment, formed amongst several motives, and the result of the concourse of actions of several faculties. There are as many desires as faculties; but there is only one will, which is the product of the simultaneous action of the intellectual forces. So that the will is frequently in opposition to the desires. The same thing applies to *liberty* and *reason;* the former merges into what has been said of the will, and the latter is only the judgment, formed by the superior intellectual faculties. In this respect, however, he remarks, it must not be confounded with intelligence; many animals are intelligent, but man alone is rational.

On the other hand, what are termed, in the intellect, *perception, memory, judgment, imagination,* &c. are attributes common to all the intellectual faculties, and cannot, consequently, be considered primary faculties. Each faculty has its perception, memory, judgment and imagination; and, therefore, there are as many kinds of perception, memory, judgment and imagination, as there are primary intellectual faculties. This is so true, he remarks, that we may have the memory and the judgment perfect upon one point, and totally defective upon another. The memory of tones, for instance, is not the same as that of language; and he, who possesses the one, may not have the other. The imaginations, again of the poet, musician, and philosopher, differ essentially from each other. These faculties are therefore, according to him, nothing more than different modes of the activity of all the faculties. Each faculty perceives the notion to which it has been attracted, or has *perception;* each preserves and renews the recollection of this notion, or has *memory.* All are disposed to act without being excited to action from without, when the organs are largely developed or have considerable intrinsic activity, which gives rise to *imagination:* and, lastly, every faculty exerts its function with more or less perfection, whence results *judgment.* *Attention*, in his view, is only the active mode of exercise of the fundamental faculties of the intellect; and, being an attribute of all, cannot be called a primary faculty.

As regards the *affective faculties*, or what have been called the *passions* and *affections*, Gall, in the first place, asserts, that the term *passion* is faulty, when used to indicate a primary faculty. It ought only to designate the highest degree of activity of any faculty. Every faculty requires to be put into action, and, according to the degree of activity, which it possesses, it is a *desire*, a *taste*, an *inclination*, a *want*, a *passion.* If it be only of the medium energy it is a *taste.* If, on the other hand, it be extremely active it is a *passion.* There may, consequently, be as many passions as there are faculties. We speak of a *passion for study*, or a *passion for music*, as we do of the *passion of love*, or that of *ambition.* Gall objects, also, to the word *affection*, which, according to him, expresses only the modifications, the primary faculties may present, according to the mode in which the external and internal influences affect them. Some of these modes are common to all the faculties, as those of *pleasure* and *pain.* Every faculty may be the occasion of the one or the other. Other affections are special to some faculties; as *pretension*, which, he says, is an affection of *pride:* and *repentance* an affection of the moral sense. Finally, these affections are *simple* or *compound: simple* when they only bear upon one faculty, as *anger*, which is a simple affection of the faculty of self-defence;—*compound*, when several faculties are affected at the same time, as *shame*, which is an affection of the primary faculties of the *moral sense*, and of *vanity.*

Gall reproaches the moralists with having multiplied too much the number of the primary affective faculties:—in his view, the modifications of a single faculty, and the combination of several, give rise to many sentiments, that are apparently different. For instance, the primary faculty of *vanity* begets *coquetry*, *emulation*, and *love of glory.* That of *self-defence* gives rise to *temerity*, *courage*, a *quarreling spirit*, and *fear.* *Contempt* is the product of a combination of the faculties of *pride* and of the *moral sense*, &c.

Lastly, as regards their psychological differences, Gall divides all men into five classes. *First.* Those in whom all the faculties of humanity predominate; and in whom, consequently, organization renders the developement of the mind and the practice of virtue easy. *Secondly.* Those in whom the organs of the animal faculties predominate; and who, being less disposed to goodness, will need the aid of education and legislation. *Thirdly.* Those in whom all the faculties are equally energetic, and who may be either excellent individuals, or great criminals, according to the direction they may take. *Fourthly.* Those who, with the rest of the faculties nearly equal and mediocre, may have one predominant. *Fifthly*, and *lastly.* Those who have the faculties alike mediocre; this is the most numerous class. It is rare, however, he remarks, that the characters and actions of men proceed from a single faculty. Most commonly, they are dependent upon the combination of several; and, as the possible combinations of so many faculties are almost innumerable, the psychological varieties of mankind may be extremely various. Again, as each of the many organs of the brain may have, in different men, a particular degree of developement and activity, seeing that each of the faculties, which are their products, has, most commonly, a special shade in every individual; as these organs can establish between each other a considerable number of combinations; and as men, independently of the differences in their cerebral organization, which gives rise to their *dispositions*, never cultivate and exert their faculties in an equal and similar manner, it may be conceived, that nothing ought to be more variable than the intellectual and moral characters of men; and we can thus explain, why there are not two men alike in this respect.

Such is an imperfect sketch of the physiological doctrine of Gall, which we may sum up in the language of the author, in his *Revue Sommaire*, appended to the sixth and last volume of his work on the "*Functions of the Brain.*"

"I have established, by a great number of proofs, as well negative as positive, and by the refutation of the most important objections, that the brain alone has the immense advantage of being the organ of the mind. Farther researches on the measure of the degree of intelligence of man and animals have shown, that the brains of animals are more simple or more complex, as their instincts, desires, and faculties are more simple or more compound; that the different regions of the brain are concerned in different categories of function; and, finally, that the brain of every species of animal, and, consequently, that of man, constitutes an aggregation of as many special organs, as there are essentially different moral qualities and intellectual faculties in the man or animal. The moral and intellectual dispositions are innate. Their manifestation is dependent upon organization. The brain is the exclusive organ of the mind. Such are four incontestable principles, forming the basis of the whole physiology of the brain;" and he adds, "the detailed developement of the physiology of the brain has unveiled the deficiencies of the hypotheses of philosophers regarding the moral and intellectual powers of man; and has been the means of bringing to light a philosophy of man, founded on his organization, and, consequently, the only one in harmony with nature."

It is impossible for us to enter, at length, into the various facts and hypotheses developed in the preceding exposition. The great points of doctrine, and the system of Gall, are:—*First.* That the brain consists of a plurality of organs, each engaged in a separate, distinct office,—the production of a special intellectual or moral faculty. *Secondly.* That each of these organs ends at the periphery of the brain, and is indicated by more or less developement of the part; and, *Thirdly.* That, by observation of the skull, we may be enabled to detect the protuberance, produced by such cerebral developement, and thus to indicate the seat of the cerebral organs of the different faculties.

It has been shown, in the preceding history, that the notion of the plurality of organs has extensively prevailed in all ages; and whatever may be the merits of the arguments adduced by Gall on this subject, it is difficult not to conceive, that different primary faculties may have their corresponding organs. Simple inspection of the brain indicates, that it consists of numerous parts, differing essentially in structure and appearance from each other; and it is but philosophical to presume, that these are adapted to equally different functions, although our acquaintance with the physiology of the organs may not be sufficiently extensive to enable us to designate them. Of the innate character of several of the faculties, described by Gall, it is scarcely possible for us to admit a doubt. Take, for instance, the *instincts of generation* and of *love of progeny.* Without the existence of these instincts, every animal species would soon be extinct. It is fair, then, to presume, that these instincts, or innate faculties, have encephalic organs, specially concerned in their production. Gall places them in the posterior part of the head,—the instinct of generation in the cerebellum; and his causes for so doing have been cited; yet, striking as his reasoning on this topic seems to be, it has been contested by many physiologists; by Broussais, Foville and Pinel-Grandchamp, Rolando, Flourens, Desmoulins, and others; and, not only by argument, but by that which must ultimately test the validity of the doctrines of the phrenologist—direct experiment. The views of these gentlemen, regarding the influence of the cerebellum, wlll be given under the head of muscular motion.

One of the greatest objections that has been brought against the system of Gall is the independence in it of the different faculties of each other. Each is made to form a separate and independent state; with no federative jurisdiction to produce harmony in their actions, or to regulate the numerous independent movements and complicated associations, which must inevitably occur in the various intellectual and moral operations. He appears, indeed, to have entirely lost sight of the important doctrine of association which applies not only to the ideas, but to every function of the frame; and with which it is so important, for the pathologist particularly, to be acquainted.

The second point of doctrine,—that each of the cerebral organs ends at the periphery of the brain, and is indicated by more or less developement of the part,—is attended with equal difficulties. It is admitted, as we have seen, by the most eminent physiologists, that the exterior part of the brain is probably chiefly concerned in the mental and moral manifestations. Almost all believe, that this function is restricted to the brain proper. Gall and his followers include the cerebellum. Yet we meet with cases, which appear to militate strongly against this notion. Hernia of the brain is one of these: in this, owing to a wound of the cranium and dura mater, a portion of the cerebral substance may protrude and be removed; yet the individual may do well; and to all appearance retain his faculties unimpaired. This is explained by the craniologist, by presuming, that as the fibres of the brain are vertical, their extremities have alone been removed, and a sufficient amount of fibres has remained for the execution of the function; and he farther entrenches himself in the difficulty of observing accurately, in these cases, whether the faculties are really in their pristine integrity. He asserts, that it is frequently extremely difficult to prove the existence of mental aberration; that the precise line of demarcation between reason and unsoundness of mind, is not easily fixed; and that commonly, in these cases, attention is paid only to the most general qualities, and if the patient is seen to take food and medicine when offered to him, to reply to questions put to him, and to have consciousness, the moral sense is esteemed to be free, and in a state of integrity.

It must, however, be admitted, that the explanation of the craniologist on these topics is feeble and unsatisfactory. It is, of course, gratuitously assuming, that observation in such cases has been insufficient; and if he finds, that the fact in question militates against the faith he has embraced, he is too apt to deny its authenticity altogether. With all the candour, which Gall possessed, this failing is too perceptible in his writings.

Again, in many of the cases of severe injury of the brain, which are on record, but one hemisphere was implicated; and, accordingly, the impunity of the intellectual and moral manifestations has been ascribed to the cerebrum being a double organ; so that, although one hemisphere may have been injured, the other, containing similar organs, may have been capable of carrying on the function; as one eye can still execute the function of vision, when the other is diseased or lost. Many cases, however, are recorded, in which this mode of explanation would not avail; and where the loss appears to have been sustained by both hemispheres, and in corresponding parts; yet the faculties have persisted.

Cases of hydrocephalic patients are likewise cited, who have preserved their faculties entire. These Gall explains, by affirming, that the brain is not dissolved in the fluid of the dropsy; that it is only deployed, and distended by the presence of the fluid; and as the distention takes place slowly, and the pressure is moderate, the organ may be so habituated to it as to be able to continue its functions.

Lastly, some experiments of Duverney have been adduced as objections to the view of Gall. These consisted in removing the whole of the brains of pigeons; yet no change seemed to be produced in their faculties; but, in reply to this, it is asserted, that Duverney could only have removed some of the superficial parts of the organ; for, whenever the experiment has been repeated, so as to implicate the deeper-seated portions, opposite results have been obtained.

The truth is, that under any view of the subject these facts are equally mysterious. We cannot understand why, in particular cases, such serious effects should result from severe injury done to the brain; and, in others, the comparative immunity attendant upon injury to all appearance equally grave. Pressure, of whatever nature, seems to be more detrimental than any other variety of mechanical mischief; and it is not uncommon for us to observe a total privation of all mental and moral acts, by the sudden effusion of blood,—of no greater magnitude than that of a pea,—into the substance of the brain; whilst a gun-shot wound, that may occasion the loss of several tea-spoonfuls of brain, or a puncture of the organ by a pointed instrument, may be entirely consistent with the existence of perfect consciousness.

The doctrine, that, by observation of the skull, we may be able to detect the protuberance produced by the cerebral organs of the different faculties, has, as we have seen, laid the foundation for the whole system of craniology, with all the extensions given to it by absurdity and vain enthusiasm. It has been remarked, that the size of an organ is but one of the elements of its activity; that, by cranioscopy, we can of course judge of this element only; and it need scarcely be said, that myriads of observations are necessary before we can arrive at any accurate specification of the seats of the cerebral faculties, even if we grant, that separate organs can be detected by the mode of examination proposed by the cranioscopist. Gall, indeed, asserts, that the whole "physiology of the brain is founded on observations, on experiments, and on researches a thousand and a thousand times repeated on man and animals;" yet the topographical division of the skull, which he has proposed, can hardly be regarded otherwise than premature, to say the least of it; and the remark of course applies *a fortiori* to that of Spurzheim.

It is this mapping of the skull, accompanied with the self-conceit and quackery of many of the *soi-disant* phrenologists or craniologists, which has excited the ridicule of those, who are opposed to the doctrine of innate faculties, and to the investigation of points connected with the philosophy of the human mind in any other mode than that, to which they have been accustomed, and are adapted. "When Gall," says Dr. Burrows,—in a recent work on insanity,—"was in England, he went in company with Dr. H. to visit the studio of the eminent sculptor, Chantry. Mr. C. being at the moment engaged, they amused themselves in viewing the various efforts of his skill. Dr. Gall was requested to say, from the organs exhibited in a certain bust, what was the predominant propensity or faculty of the individual. He pronounced the original must be a great poet. His attention was directed to a second bust. He declared the latter to be that of a great mathematician. The first was the bust of Troughton, the eminent mathematician, and the second that of Sir Walter Scott."

This kind of hasty judgment, from manifestly inadequate data, is the every day practice of the itinerant phrenologist, whose oracular dicta too often draw down ridicule not only upon the empiric himself, but on a system which is worthy of a better fate. Ridicule is, indeed, the harmless but attractive weapon, which has usually been wielded against it; and too often by those, who have been ignorant both of its principles and details.

It is not above twenty years since one of the most illustrious poets, that Great Britain has produced, included, in his satire, the stability of the cow-pox, galvanism, and gas, along with that of the metallic tractors of Perkins;—

> "The cow-pox, tractors, galvanism and gas,
> In turns appear to make the vulgar stare
> Till the swol'n bubble bursts and all is air:—"

Yet how secure in its operation, how unrivalled in its results, has vaccination every where exhibited itself!

The views of Gall are by no means established. They require numerous and careful experiments, which it is not easy for every one to institute; and this is one of the causes, why the minds of individuals will long remain in doubt regarding the merits or demerits of his system. From the mere metaphysician, who has not attended to the organization and functions of the frame, especially of its encephalic portion, it has ever experienced the greatest hostility; although his conflicting views regarding the intellectual and moral faculties was one of the grounds for the division of the phrenologist. It is now, however, we believe, generally admitted by the liberal and scientific, that if we are to attain a farther knowledge of the mental condition of man, it must be by a combination of sound psychological and physiological observation and deduction. It is time, indeed, that such a union should be effected, and that the undisguised and inveterate hostility, which exists between certainof the professors of these interesting departments of anthropology, should be abolished.

"To fulfil, definitively, the object we had proposed to ourselves in this supplement," says Broussais, in the supplement to his work, *De l'Irritation et de la Folie,*—"we must infer from all the facts and reasoning, comprised in this work,—1st. That the explanations of psychologists are romances, which teach us nothing new 2dly.

That they have no means of affording the explanations they promise. 3dly. That they are the dupes of the words they employ in disserting on incomprehensible things. 4thly. That the physiologist alone can speak authoritatively on the origin of our ideas and knowledge; and 5thly. That men, who are strangers to the science of animal organization, should confine themselves to the study of the instinctive and intellectual phenomena, in their relations with the different social states of existence."

This is neither the language nor the spirit that should prevail among the promoters of knowledge.

Lastly. Physiologists have inquired whether there is not some particular portion of the brain, which holds the rest in subservience; some part in which the mind exclusively resides;—for such was probably the meaning of the researches of the older physiologists into the seat of the soul. It is certain, that it is seated in the encephalon, but not in the whole of it; for the organ may be sliced away, to a certain extent, with impunity. Gall, we have seen, does not admit any central part of the encephalon, which holds the others in subordination. He thinks, that each cerebral organ, in turn, directs the action of the others, according as it is, at the time, in a state of greater excitation. On the other hand, different physiologists admit of a central cerebral part, which they assert to be the seat of the *moi*, or mind. They differ, however, regarding the precise situation of its domicile. At one time, the notion prevailed, that the seat of perception is not in the brain itself, but in its investing membranes. Descartes, again, embraced the singular hypothesis, that the pineal gland is entitled to this pre-eminence. This gland is a small projection, seen in Fig. 13, at the posterior part of the third ventricle, and, consequently, at the base of the brain. Being securely lodged, it was conjectured by that philosopher, that it must be inservient to some important purpose; and, upon little better grounds, he supposed, that the soul is resident there. The conjecture was considered to be confirmed by the circumstance, that, on examining the brains of certain idiots, the pineal gland was found to contain a quantity of sabulous matter. This sand was supposed to be an extraneous substance, which owing to accident or disease, was lodged in the gland and impeded its functions; and the inference was thence drawn, that the part, in which such functions were impeded, was the seat of the soul. Nothing, however, is now better established, than that the pineal gland of the adult always contains such earthy matter.

Others, again, as Bontekoe, La Peyronie, and Louis, place the mind in the corpus callosum; Vieussens in the centrum ovale; Digby in the septum lucidum; Drelincourt in the cerebellum; Sömmering in the fluid of the ventricles; and the greater part of physiologists in the point, where the sensations are received and volition sets out; the two functions, which, together, compose the *sensorial power* of Dr. Wilson Philip.*

The discrepancy amongst physiologists sufficiently demonstrates, that we have no positive knowledge on the subject.

* Darwin had previously employed this term in a more extended sense, as including the power of muscular contraction; but in Dr. Philip's acceptation, it is restricted to those physiological changes in which the mind is immediately concerned.

OF MUSCULAR MOTION,

ESPECIALLY OF LOCOMOTILITY OR VOLUNTARY MOTION.

The functions, which we have hitherto considered, give occasion to those that have now to attract our attention. The first instruct us regarding the bodies that surround us; and the second enable us to act upon them; to execute all the partial motions, that are necessary for nutrition and reproduction; to move about from one place to another, &c. &c. All these are acts of the same character: they are all varieties of muscular contraction; so that sensibility and voluntary motion comprise the whole of the life of relation. Magendie includes the voice and movements under the same head; but there is convenience in separating them, and in treating the functions of locomotility, and of expression distinctly, as has been done by Adelon.

Anatomy of the Motory Apparatus.

The organs that are essentially concerned in this function are—the encephalon, the spinal marrow, the nerves, and the muscles. The three first of these have been sufficiently described. The last, therefore, will alone engage us.

Of the Muscles.

The muscles constitute the flesh of animals. They are distinguished by their peculiar structure and composition; being formed of the elementary or primary fibrous tissue, already described. This tissue has the power of contracting, and thus of moving the parts into which it is inserted; hence, the muscles have been termed the *active* organs of locomotion, in contradistinction to the bones, tendons, and ligaments, which are *passive.*

The elementary constituent of the whole muscular system is this primary, fibrous, or muscular tissue, the precise size and intimate texture of which have been the occasion of innumerable researches; and, as most of them have been of a microscopic character, they are highly discrepant. A few of these speculations will exhibit this truth.

Leeuwenhoek asserts, that some thousands of the ultimate filaments are required to form the smallest fibre that is visible to the naked eye. He describes the fibre as serpentine and cylindrical; and affirms, that the fibres lie parallel to each other, are of the same shape in all animals, but differ greatly in their size. The size, however, bears no proportion to that of the animal to which they belong. Muys affirmed, that each apparent fibre is composed of three kinds of fibrils, progressively smaller than each other; and that those of the medium size, although not larger than the ninth part of a very delicate hair, are composed of one hundred filaments. He supposed the ultimate filament to be always of the same size. Prochaska says, that the ultimate fibre or filament is discernible, and that it is about the $\frac{1}{50}$th part of the diameter of the red globules of the blood in thickness; and MM. Prévost and Dumas, from the result of their microscopic observations, affirm, that 16,000 fibres may be contained in a cylindrical nerve, one millimeter, or 0.039 of an inch, in diameter. The intimate structure has likewise given rise to extraordinary contrariety of sentiment;—some, as Santorini, Heister, Cowper, Vieussens, Mascagni, Prochaska, Borelli, John Bernouilli, &c. believing the filaments to be hollow; others as Gottsched, Sir A. Carlisle, Fontana, and Berthier, to be solid; some believing them to be straight; others zig-zag, spiral, or waved; some jointed; others knotted, &c. &c.

Borelli and J. Bernouilli announced, that the fibre consists of a series of hollow vesicles, filled with a kind of spongy substance or marrow;—the shape of these vesicles being, according to the former, rhomboidal,—according to the latter spheroidal. Deidier conceived it to be a fasciculus, composed of an artery, vein, and lymphatic, enveloped by a nervous membrane, and held together by nervous filaments:—Prochaska, to consist of blood-vessels turned spirally around an axis of gelatinous or fibrinous substance, into the interior of which the blood rushed at the time of contraction. He says, that the visible fibres are not cylindrical, as they had been described by many observers, but of a polyhedral shape; and that they are generally flattened, or thicker in one direction than in the other. They are not all of the same diameter; differing in different animals, and in different parts of the same animal: they are smaller, too, in young subjects. The filaments, or ultimate fibres, which can only be seen with the microscope, have the same shape as the visible fibres; they are, however, always of the same magnitude.

Sir Anthony Carlisle, whose opinions, on many subjects at least, are not entitled to much weight, describes the ultimate fibre as a solid cylinder, the covering of which is a reticular membrane, and the contained part a pulpy substance, regularly granulated, and of very little cohesive power when dead. The extreme branches of the blood-vessels and nerves, he says, are seen ramifying on the surface of the membrane inclosing the pulp, but cannot be traced into the substance of the fibre. Mr. Bauer and MM. Prévost and Dumas, again, differ essentially from the observers already mentioned. Mr. Bauer found, that the muscular fibre was composed of a series of globules, arranged in straight lines; the size of the globule being $\frac{1}{2000}$th part of an inch in diameter; and lastly, Raspail considers that the intimate structure of the muscular tissue, when it is in its most simple state, consists of a bundle of cylinders, intimately agglutinated together, and disposed, in a very loose spiral form, around the ideal axis of the group. These tubes are filled with a substance not wholly miscible with water, and may be regarded as elongated vesicles, united at each end to other vesicles of a similar character.

When a muscular fibre is seen through an ordinary microscope, it appears to be composed of longitudinal filaments, each consisting of a string of globules, about $\frac{1}{8000}$th of an inch in diameter. "But with a better instrument," says Mr. Mayo, "such as that, which Mr. Lister possesses, the delusion vanishes, and the parallel lines, which traverse the fibre, appear perfectly clean and even. Mr. Lister politely gave me an opportunity of examining this appearance, which was discovered by himself and Dr. Hodgkin."

The ultimate fibres, or filaments, when united in bundles, form *fasciculi* or *lacerti:* and these, by their aggregation, constitute the various muscles. Each fibre, each lacertus, and each muscle, is surrounded by a sheath of cellular tissue, which enables them to move readily upon each other, and preserves them *in situ*. The fibres are not the same at the extremities, as they are at the middle. The latter only consist of the proper muscular tissue; the extremities being formed of cellular tissue. If we examine a muscle, we find, that the proper muscular fibres become gradually fewer, and at length cease to be perceptible, as they approach the tendon at one or other extremity. In this way, the cellular membrane, which surrounds every fibre, becomes freed from the muscular tissue; its divisions approximate, and become closely united and condensed, so as to form the *cord* or *tendon*, which, of course, holds a relation to each fibre of the muscle; and when they all contract, the whole force is exerted upon it. This arrangement will explain the close union which exists between the muscle and its tendon, and which has given occasion to the belief, that the latter is only the former condensed. An examination of some of the physical and vital properties of the two will show, that they differ as essentially as any two of the constituents of the body that could be selected. The tendon consists chiefly of gelatine, and does not exhibit the slightest irritability; whilst the muscle is formed essentially of fibrine, and contracts under the will, as well as on the application of certain mechanical and chemical irritants. The differences, in short, that exist between the two, are such as distinguish the primary fibrous and cellular tissues; yet the opinion of their identity prevailed in antiquity, was embraced by Boerhaave and his school, and, as Dr. Bostock observes, was so generally admitted, even in the middle of the last century, that Haller and Sabatier scarcely ventured to give a decided opposition to it.

Similar remarks are applicable to the notion of Cullen, that muscles are only the moving extremities of nerves. The fibres of the muscle were supposed by him to be continuous with those of the-nerve;—to be, indeed, the same substance, but changed in structure, so that when the nerve is converted into muscle, it loses the power of communicating feeling, and acquires that of producing motion.

Every muscle and every fibre of a muscle is probably supplied with blood-vessels, lymphatics and nerves. These cannot be traced into the ultimate filament, but, as this must be possessed of life and be contractile under the will, it must receive through the blood-vessels and nerves the appropriate vital agents. M M. Dumas and Prévost, however, affirm, that the microscope shows, that neither the one nor the other terminates in the muscle. The vessels merely traverse the organs; the arteries terminating in corresponding veins; so that the nutrition of the muscles is effected merely by the transudation of the blood through the parietes of the artery;—a notion, which is liable to weighty objection, inasmuch as blood is not muscle, but requires a true action of selection or of elaboration to be exerted upon it, before it can become so. A similar distribution they assign to the nerves. All the branches they assert, enter the muscle in a direction perpendicular to that of the fibres composing it; and their final ramifications, instead of terminating in the muscular fibres, surround them loopwise and return to the trunk that furnished them, or anastomose with some neighbouring trunk. In their view, each nervous filament, distributed to the muscles, sets out from the anterior column of the spinal marrow, forming part of a nervous trunk, turns round one or more muscular fibres, and returns along the same or a neighbouring trunk to the posterior column of the marrow.

The red colour of muscles is usually ascribed to the blood distributed to them, as it may be removed by repeated washing and maceration in water or alcohol, without the texture of the muscle being modified. By some, it has been thought, that a quantity of red blood remains attached to the fibres, and is extravasated from the vessels; by others, it is presumed, with more probability perhaps, to be still contained in the vessels. Bichat conceived, that the colour is dependent upon some foreign substance combined with the fibre; and he grounds his opinion upon the circumstance, that, in the same animal, some of the muscles are always much redder than others; and yet they do not appear to have a greater quantity of blood sent to them; and also that, in different classes of animals, the colour of the muscles does not appear to correspond with the quantity of red blood circulating through their vessels. The fact, however, that, when muscles have been long in a state of inaction, they become pale; and that, on the other hand the colour becomes deeper, when they are exercised, is an additional evidence, that their colour is dependant upon the blood they receive, which is found to diminish or increase in quantity, according to the degree of inactivity or exertion.

The muscles differ, like the primary fibre, at their extremities and centre; the former being composed of condensed cellular membrane, the latter of the muscular or fibrous tissue. The centre of a muscle is usually called its *venter* or *belly*, and the cellular texture at the extremities is variously termed;—the part, from which it appears to arise, being called the *head* or *origin;* and that, into which it is inserted, the *tail*, *termination*, or *insertion*. These terms are not sufficiently discriminative. We shall find, that a muscle is capable of acting in both directions, so that the head and the tail—the origin and insertion—reciprocally change places. In ordinary language, however, the extremity at which the *albugineous* tissue, (if we adopt Chaussier's nomenclature,) assumes a round form, so as to constitute a cord or *tendon*, is called the insertion. When this tissue is expanded into a membrane, it is termed an *aponeurosis:* and in this state it exists at the head or origin of the muscle; so that by tendon and aponeurosis the muscles are inserted into the parts, which they are destined to move, if we except those that are inserted into the skin.

Muscles are divided into *simple* and *compound*. The *simple* are those whose fibres have a similar course and arrangement. They may be either *flat* or *ventriform*, or *radiated* or *penniform*. The *compound* arise from different parts; their origins are, consequently, by distinct fasciculi, or they may terminate by distinct insertions. Fig. 57, which is a representation of the biceps—a flexor muscle of the forearm—is one of these. It has, as its name imports, two heads running into one belly. It is, also, an example of the *ventriform* muscle.

Fig. 57.

In the pectoralis major, Fig. 58, we have an exmple of the *radiated* muscle, or of one in which the fibres converge towards their tendinous insertion.

Fig. 58.

In the *penniform* muscle, the fibres run in a parallel direction, but all are inserted obliquely into the tendon, like the feathers of a quill, Fig. 59 is a representation of a *double penniform* muscle. Muscles may, also, be *complicated:* that is, with one belly, and several tendons, having the fibres variously inserted into them, or having several bellies with the tendons interlaced.

Fig. 59.

They are, again, partitioned into the *long*, *broad*, and *short*. The *long* muscles are situated chiefly on the limbs, and are concerned in locomotion. The *broad* generally form the parietes of cavities; they are not so much enveloped as the long muscles by strong fibrous aponeuroses or fasciæ, owing to their being obviously less liable to displacement; and the *short* muscles are situated in parts, where considerable force is required, and but little motion; so that their fibres are very numerous and short.

The number of muscles of course varies in different animals; and is in proportion to the extent and variety of motion they are called upon to execute. In man, the number is differently estimated by anatomists; some describing several distinct muscles under one name; and others dividing into many what ought to belong to one. According to the arrangement of Chaussier, three hundred and sixty-eight distinct muscles are admitted; but others reckon as many as four hundred and fifty.

When muscles are subjected to analysis, they are found to consist of fibrine, osmazome, jelly, albumen, phosphates of soda, ammonia and lime, carbonate of lime, muriate, phosphate, and lactate of soda; and, according to Fourcroy and Vauquelin, sulphur and potassa are present. The great constituents of the pure muscular tissue are,—fibrine, and probably osmazome;—the gelatine, which is met with, being ascribable to the cellular membrane that envelopes the muscular fibres and lacerti. The membranous structures of young animals contain a much greater quantity of jelly than those of the adult; and it is probably on this account, that the flesh of the former is more gelatinous;—not because the muscular fibre contains more gelatine.

Thénard assigns the muscles, on final analysis, the following constituents:—Fibrine, albumen, osmazome, fat, substances capable of passing to the state of gelatine, acid (lactic,) and different salts. It must be borne in mind, as Raspail has properly remarked, that these are the results of the analysis of the muscle, as we meet with it. The analysis of the muscular fibre has yet to be accomplished. In this, too, and every analogous case, the analysis only affords us evidence of the constituents of the dead animal matter; and some of the products may even have been formed by the new affinities, resulting from the operations of the analyst. They can afford us but an imperfect judgment of the constitution of the living substance.

The muscular structure is liable to a singular kind of conversion, under particular circumstances, to which it may be well to advert. When, about the latter part of the last century, it was determined, for purposes of salubrity, to remove the bodies from the church-yard of *Les Innocens* at Paris—which had been the cemetery for a considerable part of the population of Paris for centuries—the whole area, occupying about seven thousand square yards, was found converted into a mass, consisting chiefly of animal matter, and raising the soil several feet above its natural level. On opening the ground, to remove the prodigious collection of dead bodies, they were found to be strangely altered in their nature and appearance. What had constituted the soft parts of the body was converted into an unctuous matter, of a gray colour, and of a peculiar, but not highly offensive, smell. According to their position in the pits,—for the bodies were deposited in pits or trenches, about thirty feet deep, each capable of holding from twelve hundred to fifteen hundred bodies,—and according to the length of time they had been deposited, this transformation had occurred to a greater or less extent. It was found to be most complete in those bodies, which were nearest the centre of the pits, and when they had been buried about three years. In such case, every part, except the bones, the hair, and the nails, seemed to have lost all its properties, and to be converted into this *gras des cimetières*, which was found to be a saponaceous compound, consisting of ammonia, united to *adipocire*,—a substance, as its name imports, possessing properties intermediate between those of fat and wax. When the adipocire was freed from the ammonia, and obtained in a state of purity, it was found to resemble strongly spermaceti, both in physical and chemical qualities.

It was afterwards discovered, that the conversion of muscular flesh into adipocire might be caused by other means. Simple immersion in cold water, especially in a running stream, was found by Dr. Gibbes to produce the conversion more speedily than inhumation. It can be caused, too, still more rapidly by the action of dilute nitric acid.

The chemical is not the only interest attached to this substance. It has been invoked in a court of justice, for the purpose of enabling some judgment to be formed regarding the period that a body may have been immersed in the water. It is probable that this must differ greatly according to various circumstances;—the time that has elapsed between the death of the individual, and the period of immersion; the conditions of the fluid as to rest or motion, temperature, &c.; and the temperature of the atmosphere; so that any attempt to fix a period for such conversion must be liable to much inconclusiveness. Yet the opinion of a medical practitioner, on this subject, has been the foundation of a juridical decision. At the lent assizes, holden at Warwick, England, in the year 1805, the following case came before the court. A gentleman, who was insolvent, left his home, with the intention,—as was presumed from his previous conduct and conversation,—of destroying himself. Five weeks and four days after that period, his body was found floating down a river. The face was disfigured by putrefaction, and the hair separated from the scalp by the slightest pull; but the other parts of the body were firm and white, without any putrefactive appearance. On examining the body, it was found that several parts of it were converted into adipocire.

A commission of bankruptcy having been taken out against the deceased a few days after he left home, it became an important question, to the interest of his family, to ascertain whether or not he was living at that period. From the changes sustained by the body, it was presumed that he had drowned himself on the day he left home; and to corroborate the presumption, the evidence of Dr. Gibbes was requested, who, from his experiments on this subject, it was thought, was better acquainted with it than any other person. Dr. Gibbes stated on the trial, that he had procured a small quantity of this fatty matter, by immersing the muscular parts of animals in water for a month, and that it required five or six weeks to make it in any large quantity. Upon this evidence, the jury were of opinion that the deceased was *not alive* at the time the commission was taken out, and the bankruptcy was accordingly superseded!

Of the Bones.

The bones are the hardest parts of the animal frame; and, consequently, serve as a base of support and attachment to the soft parts. They constitute the frame-work of the body, and determine its general shape. The principal functions they fulfil are,—to form defensive cavities for the most important organs of the body—the encephalon, spinal marrow, &c.—and to act as so many levers for transmitting the weight of the body to the soil, and for the different locomotive and partial movements. To them are attached the different muscles, concerned in those functions. In man and the higher classes of animals, the bones are, as a general rule, within the body; his *skeleton* is, consequently, said to be internal. In the crustacea, the testaceous mollusca, and in certain insects, the skeleton is external, the whole of the soft parts being contained within it. The lobster and crab are familiar instances of this arrangement.

The stature of the human skeleton is various, and may be taken, on the average, perhaps,—in those of European descent,—at about five feet eight or nine inches. We find, however, examples of considerable variation from this average. A skeleton of an Irish giant, in the museum of the Royal College of Surgeons of London, measures eight feet four inches. On the other hand, Bebe, the dwarf of

Stanislaus, king of Poland, was only thirty-three inches high; and a Polish nobleman, Borwlaski, measured twenty-eight French inches. He had a sister, whose height was twenty-one inches.

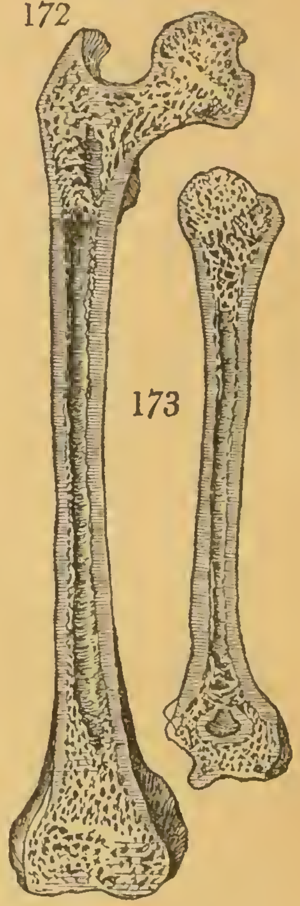
The bones may be divided into the *short*, *broad* or *flat*, and *long*. The *short* bones are met with in parts of the body, which require to be both solid and moveable:—in the hands and feet for example, and in the spine. The *flat* or *broad* bones form the parietes of cavities, and they aid materially in the movements and attitudes, by affording an extensive surface for the attachment of muscles. The *long* bones are chiefly intended for locomotion, and are met with only in the extremities. The shape of the *body* or *shaft*, and of the extremities, merits attention. The shaft or middle portion is the smallest in diameter, and is usually cylindrical. The extremities, on the other hand, are expanded; a circumstance, which not only adds to the solidity of the articulations, but diminishes the obliquity of the insertion of the tendons, passing over them, into the bones. In their interior is a medullary canal or cavity, which contains the *medulla*, *marrow*, or *pith*:—a secretion, whose office will be a theme for after inquiry. One great advantage of this canal is, that it makes the bone a hollow cylinder, and thus diminishes its weight. On many of the bones, prominences and cavities are perceptible. The eminences bear the generic name of *apophyses* or *processes*. Their great use is, to cause the tendons of muscles to be inserted at a much greater angle into the bones they have to move. It will be seen hereafter, that the nearer such insertion is to the perpendicular to the lever, the greater will be the effect produced.

The cavities are of various kinds. Some are *articular:* others for the insertion, reception, or transmission of parts. Those of insertion and reception afford space for the attachment of muscles; those of transmission, &c. are frequently incrusted with cartilage, converted into canals by means of ligament, and furnished with a synovial membrane, which lubricates them, and facilitates the play of the tendons, for the passage of which they are destined.

The mechanical structure of bone is a laminated frame-work, incrusted by an earthy substance, and penetrated by exhalant and absorbent vessels, arteries, veins, and nerves. Herissant, in 1758, appears to have been one of the first who stated, that bone is essentially composed of two substances:—the one a cartilaginous basis or parenchyma, giving form to the part,—the other a peculiar earthy matter, deposited in this basis, and communicating to it its hardness. These two constituents can be readily demonstrated; the *first*, by digesting the bone in dilute muriatic acid, which dissolves the earthy part, without acting on the animal matter; and the *second*, by burning the bone, until all the animal matter is consumed, whilst the earthy part is left untouched.

If we take a long bone and divide it longitudinally, we find, that it is composed of three different substances, all of which may, however, be regarded as the same osseous tissue, in various degrees of condensation. These are,—the *hard* or *compact* substance, the *spongy* or *areolar*, and the *reticulated*. The first is in the most condensed form; it exists at the exterior of the bone, and constitutes almost the whole of the shaft. The second is seen towards the extremities of the long bone, and in almost the whole of the short bones. In it, the laminæ are less close, and have a cancellated appearance,—the cellules bearing the name of *cancelli*. The reticulated substance is a still looser formation; the laminæ being situated at a considerable distance, and the space between filled up with a series of membranous cells, which lodge the marrow. The marginal figures represent a longitudinal section of the os femoris, and os humeri, in which this arrangement is well exhibited.

Fig. 60.



We have seen the advantages of the expanded extremities of long bones, as regards the insertion of muscles; but it is obvious, that if these portions of the bone had consisted of the heavy compact tissue, the increased weight of the limbs would have destroyed the advantages, which would otherwise have accrued; whilst, if the shaft of the bone, exposed, as it is, to external violence, had consisted of the spongy tissue only, it would not have been able to offer the necessary resistance. It is, therefore, formed almost entirely of the compact tissue; so that a section of one inch in height, taken from the body of the bone, will not differ essentially in weight from an inch taken from the extremity. Nor does the cavity, within the bones, diminish their strength as might be at first sight presumed. By enlarging the circumference, the contrary effect is produced; for we shall see, in the mechanical proem to the particular movements, that of two hollow columns, formed of an equal quantity of matter and of the same height, that, which has the larger cavity, is actually the stronger. A very important use of the cancellated or spongy texture of the bones has been suggested by a distinguished individual of this country, to whom surgical science, in particular, has been so largely indebted. Dr. Physick asserts, that it serves to diminish, and, in many cases, to prevent, concussion of the brain, and of the other viscera, in falls and blows. The demonstration, which he gives of this, is simple and satisfactory. If we suspend a series of six ivory balls by threads; raise the ball at one extremity, and allow it to fall on the next to it, we find, that the farthest ball in the series is impelled to a distance, which corresponds to the momentum communicated by the first ball to the second. But if we substitute, for the middle ball of the series, a ball made of the cellular structure of bone, we find that almost the whole of the momentum is lost in this osseous structure; especially, if it be previously filled with tallow or well soaked in water, so as to bring it to a closer approximation to the natural, living condition.

Bones consist of earthy salts and animal matter intimately blended. The latter is chiefly cartilage, gelatine, and the peculiar fatty matter—the marrow. On reducing bones to powder and digesting them in water, the fat rises and swims upon its surface, and the gelatine is dissolved.

According to the analysis of Berzelius, 100 parts of dry human bones consist of animal matter, 33.3; phosphate of lime, 51.04; carbonate of lime, 11.30; fluate of lime, 2; phosphate of magnesia, 1.16; and soda, muriate of soda, and water, 1.2. Fourcroy and Vauquelin did not detect any fluoric acid, but they found oxides of iron and manganese, silica, and albumen. Hatchett detected, also, a small quantity of sulphate of lime.

The bones are enveloped by a dense fibrous membrane, termed, in the abstract, *periosteum:* but assuming different names according to the part it covers. On the skull, it is called *pericranium:* and its extensions over the cartilages of prolongation, are called *perichondrium.* The chief uses of this expansion are, to support the vessels in their passage to and from the bone, and to assist in its formation; for we find, that if the periosteum be removed from a bone, it becomes dead at the surface previously covered by the membrane, and exfoliates. In the fœtus, it adds materially to the strength of the bone, prior to the completion of ossification. In the long bones, ossification commences at particular points; one generally in the shaft, and others at the different articular and other processes. These ossified portions are, for some time, separated from each other by the animal matter, which, alone, composes the intermediate portions of the bone; and, without this fibrous envelope, they would be too feeble perhaps to resist the strains to which they are exposed. The periosteum, moreover, affords a convenient insertion for the muscles destined to act upon the bones; and enables them to slide more readily when in action; hence friction is avoided.

The cavity of long bones is lined by a membrane—called the *medullary membrane* or *internal periosteum*—which is supplied with numerous vessels, adheres to the interior surface of the bone, and is not only concerned in its nutrition, but also in the secretion of the *marrow,*—and likewise of a kind of oily matter, which differs from marrow merely in being more fluid, and is contained in the cells, formed by the spongy substance, and in the areolæ of the compact substance. This is called the *oil of bones.*

The marrow is considered to be lodged in membranous cells, formed by an extension of the internal periosteum; whilst, according to Howship, the oil of bones is probably deposited in longitudinal canals, which pass through the solid substance of the bone, and through which its vessels are transmitted.

The nature and fancied uses of the marrow and of the oil of bones will be considered in another part.

The bones, periosteum and marrow are, in the sound state, amongst the insensible parts of the frame. They are certainly not sensible to ordinary irritants; but, when morbid, they exhibit intense sensibility. This, at least, applies to the bones and periosteum; the sensibility, which has been ascribed to the marrow, in disease, being probably owing to that of the prolongations of the membrane, in which it is contained.

The number of the bones in the body is usually estimated at two hundred and forty, exclusive of the *sesamoid* bones, which are always found in pairs at the roots of the thumb, and great toe, between the tendons of the flexor muscles and joints, and, occasionally, at the roots of the fingers and small toes.

In the following Table of the Bones, the numbers on the left hand correspond with those of the accompanying plates of the skeleton.

TABLE OF THE BONES.

			HOW MANY.
Bones of the Head.	Bones of the *Cranium* or *Skull*,	1. Frontal,	1
		2. Parietal,	2
		5. Occipital,	1
		3. Temporal,	2
		Ethmoid,	1
		4. Sphenoid,	1
	Bones of the *Face*,	7. Superior Maxillary,	2
		6. Malar or cheek,	2
		Nasal,	2
		Lachrymal,	2
		Palatine,	2
		Inferior Spongy,	2
		Vomer,	1
		8. Inferior Maxillary,	1
	Dentes or *Teeth*,	Incisores,	8
		Cuspidati,	4
		Molares,	20
	Bone of the *Tongue*,	Hyoid,	1
	Bones of the *Ear*,	Malleus,	2
		Incus,	2
		Orbiculare,	2
		Stapes,	2
Bones of the Trunk.	*Vertebræ*,	9. 10. 11. Cervical (9. Atlas and 10. Dentata,)	7
		12. Dorsal,	12
		13. Lumbar,	5
	Sacrum,		1
	Os Coccygis,		1
	The *Thorax*,	14. Sternum,	1
		15. 16. Ribs (15. True ribs, and 16. False ribs,)	24
	The *Pelvis*,	25. 28. Innominatum, comprising 29. Ilium, 30. Ischium, and 31. Pubis,	2

BONES OF THE UPPER EXTREMITY.	The *Shoulder*,		17. Clavicle,	2
			18. Scapula,	2
	The *Arm*,		19. Humerus,	2
	The *Forearm*,		21. Ulna,	2
			20. Radius,	2
	The *Hand*,	*Carpus* or *Wrist*, 22.	Naviculare,	2
			Lunare,	2
			Cuneiforme,	2
			Orbiculare,	2
			Trapezium,	2
			Trapezoides,	2
			Magnum,	2
			Unciforme,	2
		23. Metcarpus,		10
		24. Phalanges,		28
BONES OF THE LOWER EXTREMITY.	The *Thigh*,		32. Femur,	2
	The *Leg*,		33. Patella,	2
			34. Tibia,	2
			35. Fibula,	2
	The *Foot*, 38.	*Tarsus* or *Ankle* or *Instep*, 36.	37. Os Calcis,	2
			Astragalus,	2
			Cuboides,	2
			Naviculare,	2
			Cuneiforme,	6
		39. Metatarsus,		10
		40. Phalanges,		28
			Total,	240

The bones are connected by means of *articulations* or *joints*, which differ materially from each other. To all the varieties, technical names are appropriated, which form a difficult task for the memory of the anatomical student. Technically, every part, at which two bones meet and are connected, is called an *articulation*, whether any degree of motion is permissible or not. This capability, indeed, is the foundation of the division that prevails at the present day, all the articulations being separable into two classes:—the *immovable* or *synarthroses:* and the *movable* or *diarthroses.*

The *synarthroses* are variously termed, according to their shape. When the articular surfaces are dove-tailed into each other, the joint is called a *suture.* This is the articulation that prevails between the bones of the skull. *Harmony* is when the edges of the bones are even, and merely touch, as in the bones of the head in quadrupeds and birds. When a pit in one bone receives the projecting extremity of another, we have a case of *gomphosis.* It is exhibited in the union between the teeth and the sockets. Lastly, *schindylesis,* is when the lamina of one bone is received into a groove of another; as in the articulation of the vomer, which separates the nasal fossæ from each other.

The *movable articulations* comprise two orders:—the *amphiarthroses*, in which the two bones are intimately united by an intermediate substance, of a soft and flexible character—as in the junction of the vertebræ with each other, and the *diarthroses*, properly so called. The last admit of three subdivisions—the *enarthroses* or *ball* *and socket joints*;—the *condyloid*, in which, owing to the head being oval, the movements are not as easy in all directions as where the head is spherical; and the *ginglymoid* or *ginglymus*, in which the motion can occur only in one direction as in a hinge. The farther subdivision of the joints belongs more to anatomy than physiology.

The articular surfaces of the bones never come into immediate contact. They are tipped with a firm, highly elastic substance, called *cartilage*; which, by its smoothness, enables the bones to move easily upon each other, and may have some influence in deadening shocks, and defending the bones, which it covers. The arrangement of the cartilage varies according to the shape of the extremity of the bone. If it be spherical, the cartilage is thick at the centre, and gradually diminishes towards the circumference. In a cavity the reverse is the case: the cartilage is thin at the centre, and becomes thicker towards the circumference; and on a trochlea or pulley, its thickness is nearly every where alike.

An admirable provision against displacement of the bones at the articulations exists in the ligaments. These, by the French anatomists, are distinguished into two kinds—the *fibrous capsules*, and the *ligaments* properly so called. The former are a kind of cylindrical sac, formed of a firm, fibrous membrane; open at each extremity, by which they closely embrace the articular end of the bones; and loose, when the joint admits of much motion. In this way, the articulation is completely inclosed: they generally bear the name of *capsular ligaments*.

The *ligaments*, properly so called, are bands of the same kind of tissue, which extend from one bone to another; by their resistance preserving the bones in situ; and by their suppleness admitting of the necessary motion.

The interior of all these articulations is lubricated by a viscid fluid, called the *synovia*. This is secreted by a peculiar membrane of a serous nature; and its use is to diminish friction, and, at the same time, to favour adhesion. The mode in which it is secreted, and its chief properties and uses, will be the subject of future inquiry.

In certain of the movable articulations, fibro-cartilaginous substances, frequently called *interarticular cartilages*, are found between the articular surfaces, and not adherent to either of them. These have been supposed to form a kind of cushion, which, by yielding to pressure, and returning upon themselves, may thus protect the joints to which they belong; and, accordingly, it is asserted, that they are met with in the joints, which have to sustain the greatest pressure; but Magendie properly remarks, that they do not exist in the hip-joint, or in the ankle-joint, which have constantly to support the strongest pressure. The use, which he suggests, is more specious;—that they may favour the extent of motion, and prevent displacement.

The stability of the joints is likewise aided by the manner in which the muscles or tendons pass over them. These are contained in an aponeurotic sheath, to prevent their displacement; and thus the whole limb becomes well protected, and dislocation infrequent, even in those joints, as that of the shoulder, which, as regards their osseous arrangement, ought to be very liable to displacement.

Physiology of Muscular Motion.

By *voluntary motion* we mean a contraction of the muscles under the influence of *volition* or the *will.* This influence is propagated along the nerves to the muscles, which are excited by it to contraction. The *encephalon*, *spinal marrow*, *nerves*, and *muscles*, are, therefore, the organs of voluntary contraction.

Volition is one of the functions of the encephalon, and might have been, with much propriety, included under the physiology of the intellectual and moral acts; but as it is so intimately concerned with muscular motion, it was judged advisable to defer its consideration until the present occasion.

That volition is a product of encephalic action is proved by many facts. If the brain be injured in any manner;—by fracture of the skull, for example, or by effusion of blood, producing apoplectic pressure on some part of it;—or if it be deprived of its functions by the use of a strong dose of any narcotic substance;—or if, again, it be in a state of rest, as in sleep:—volition is no longer exerted, and voluntary motion is impracticable. This is the cause why the erect attitude cannot be maintained during sleep; and why the head falls forward upon the chest, when the somnolency is to such an extent as to deprive the extensor muscles of the back and head of their stimulus to activity.

That an emanation from the encephalon is necessary is likewise proved by the effect of tying, cutting, compressing, or stupefying the nerve proceeding to a muscle: it matters not, that the will may act; the muscle does not receive the excitant, and no motion is produced; a fact which proves, that the nerves are the channels of communication between the brain and the muscles.

If, again, we destroy the medulla oblongata and medulla spinalis, we abolish all muscular motion, notwithstanding the brain may will, and the muscles be in a state of physical integrity; because we have destroyed the parts whence the nerves proceed. In like manner, by successively slicing away the medulla spinalis from its base to the occiput, we paralyze, in succession, every muscle of the body, which receives its nerves from the spinal marrow.

Experiments of different physiologists have confirmed the view, that the encephalon is the chief seat of volition. When it has been sliced away to a certain extent, the animal has been thrown into a state of stupor, attended with the loss of sensibility, of the power of locomotion, and especially of spontaneous motion; and in writing, dancing, speaking, singing, &c. we have indisputable evidence of its direction by the intellect.

It is not so clear, that the seat of volition is entirely restricted to the encephalon. There are many actions of the yet living trunk, which appear to show, that an obscure volition may be exerted, even after the brain has been separated from the rest of the body; and acephalous children have not only moved perceptibly when in utero, but at birth. Without referring to the lower classes of animals, which, as we have already had occasion to remark, execute voluntary motions for a long time after they have been bisected, every one must have noticed the motions of decapitated fowls, which will continue, for a time, to run and leap, and, apparently, to suffer uneasiness in the incised part.

The feats of the emperor Commodus are elucidative of this matter. Herodian relates, that he was in the habit of shooting at the ostrich, as it ran across the circus, with an arrow having a cutting edge; and, although the shaft was true to its destination, and the head was severed from the body, the ostrich usually ran several yards before it dropped. Kaauw Boerhaave—the nephew of the celebrated Hermann, and himself an eminent medical teacher at St. Petersburgh—asserts, that he saw a cock, thus decapitated, run for a distance of twenty-three feet afterwards. Some cases are also recorded of men walking a few steps after decapitation, striking their breasts, &c.; but they can scarcely be regarded as authentic. In those countries, where judicial execution consists in decapitation by the sword, sufficient opportunities must have presented themselves for testing this question; but no zealous Naturforscher appears to have been present to record them. Similar opportunities have likewise occurred, under the operations of the guillotine.

Legallois, in some experiments, which he instituted, for the purpose of determining the nervous influence on the heart, &c., found, that rabbits, which he had decapitated and deprived of their hinder extremities, but still kept alive by artificial respiration, moved their fore paws, whenever he stimulated them by plucking some of their hairs.

With regard to complete acephali, or those fœtuses which are totally devoid of encephalon,—although they may vegetate in utero, they quickly expire after birth, owing to their being devoid of the organs of the animal functions, and the consequent impossibility of respiration. Some monsters have, however, been born without the brain, but with a part of the encephalon. These have been called, by way of distinction, *anencephali* or *hemicephali*. Where the medulla oblongata exists, they possess the nervous system of the senses, and are, consequently, able to live for some time after birth, and to exert certain muscular movements, such as sucking, moving the limbs, evacuating the excretions, &c.

Professor Adelon asserts, that none of these facts ought to shake the proposition, which he embraces; that in the superior animals, and consequently in man, the medulla spinalis and the nerves are merely the conductors of volition, or of the locomotive will; and that, in the encephalon alone, volition is produced. His arguments on this point, however, are not characterized by that ingenuousness and freedom from sophism, for which his physiological disquisitions are generally distinguished.

"First of all," he observes, "the fact of the progression and motions of men and quadrupeds, after decapitation, is manifestly apocryphal; and even if we must admit, that certain animals still execute some movements after decapitation, are such movements evidently regular and ordained? And, supposing them to be so, may not this have arisen from the conformation of the parts, or from habits contracted by the organs? This last appears to us most probable; for if, from any cause whatever, the muscles of a part contract, they will cause the part to execute such motions as the joints, entering into its composition, require; and which may, therefore, be similar to those that the will produces." He farther attempts to deny the facts related of the lower classes of animals, and asserts, that "they are not evinced in the experiments instituted in our day."

The cases, which are adduced to prove the defective sensibility of the lower tribes of animated nature, are, however, incontestable; —the trunk of the wasp will attempt to sting after the head is removed; and the experiment, which was made by Dr. Harlan, in the presence of Capt. Basil Hall, certainly demonstrates something like design in the headless trunk.

Our conclusion ought probably to be, from all these cases,—that volition is chiefly seated in the encephalon, but that an obscure volition may, perhaps, extend over the whole of the cerebro-spinal axis. This conclusion, of course, applies only to the higher classes of animals; for we have seen, that the polypus is capable of division into several portions, so as to constitute as many distinct beings; and it is probable, that the principal seat of volition may extend much lower down in the inferior tribes.

Attempts, and of a successful nature, have been made to discover, whether the whole brain is concerned in volition, or only a part. Portions of the brain have been disorganized by disease, and yet the individual has not been deprived of motion; at other times, as in paralysis, the faculty has been impaired; and again, considerable quantities of brain have been lost, owing to accidents, (in one case the author knew nineteen tea-spoonfuls,) with equal immunity, as regards the function in question.

The experiments, executed on this subject, go still farther to confirm the idea, that volition is not seated exclusively in the encephalon. Rolando and Flourens performed several, with the view of detecting the seat of the locomotive will; or of that which presides over the general movements of station and progression; and they fixed upon the cerebral lobes. Animals, from which these were removed, were thrown into a sleepy, lethargic condition; were devoid of sensation and spontaneous motion, and moved only when provoked.

On the other hand, Magendie affirms, that the cerebral hemispheres may be cut deeply in different parts of their upper surface, without any evident alteration in the movements. Even their total removal, if it did not implicate the corpora striata, he found to produce no greater effect; or, at least, none but what might be easily referred to the suffering induced by such an experiment. The results, however, are not alike in all the classes of vertebrated animals. Those, detailed, were observed on quadrupeds, and particularly on dogs, cats, rabbits, Guinea-pigs, hedge-hogs, and squirrels. In birds, the removal or destruction of the hemispheres—the optic tubercles remaining untouched—was often followed by the state of stupor and immobility, described by Rolando and Flourens; but, in numerous cases, the birds ran, leaped, and swam, after the hemispheres had been removed, the sight alone appearing to be destroyed. In reptiles and fish, the removal of the hemispheres seemed to exert but little effect upon their motions. Carps swam with agility; frogs leaped and swam as if uninjured, and the sight did not appear to be affected.

Magendie properly concludes, from these experiments, that the spontaneity of the movements does not belong exclusively to the hemispheres; that in certain birds, as the pigeon, the adult rook, &c. this seems to be the case; but not so in other birds; but as regards the mammalia, reptiles, and fish,—at least such of them as were the subjects of his experiments,—his conclusion is applicable.

Of the nature of the action of the brain, in producing volition, we know nothing. It is only in the prosecution of direct experiments upon the organ, that we can have an opportunity of seeing it, during the execution of the function; but the process is too minute to admit of observation. Our knowledge is confined to the fact, that the encephalon does act, and that some influence is projected from it along the muscles, which excites them to action, and accurately regulates the extent and velocity of muscular contraction. Yet volition is not the sole excitant of such contraction. If we irritate any part of the encephalon or spinal marrow, or any of the nerves proceeding from them, we find, that muscular movements are excited; but they are not regular, as when under the influence of volition. The whole class of *involuntary motions* is of this kind, including the action of many of the most important organs—the heart, intestines, blood-vessels, &c. All the involuntary muscles equally require a stimulus to excite them into action; but, as their name imports, they are removed from the influence of volition, and instead of receiving their nerves directly from the brain or spinal marrow,—as the organs of voluntary motion do,—they are supplied from the organic nervous system, or the system of the great sympathetic. In certain diseased conditions, we find, that all the voluntary muscles assume involuntary motions; but this is owing to the ordinary volition being interfered with, and to some direct or indirect stimulation, affecting the parts of the cerebro-spinal axis concerned in muscular contraction; or, if the effect be local, to some stimulation of the nerve proceeding from the axis to the part. Of this kind of general involuntary contraction of voluntary muscles, we have a common example in the convulsions of children; and one of the partial kind, in cramp or spasm.

The will, then, is the great but not the sole regulator of the supply of nervous influence. This is confirmed by experiment. If a portion of the spinal marrow be divided, so as to separate it from all communication with the encephalon, the muscles cannot be affected by the will; but they contract on irritating the part of the spinal marrow, from which the nerves proceed. It has, hence, been presumed, by some physiologists, that volition is only the exciting and regulating cause of the nervous influence; and that the latter is the immediate agent in producing contraction; and they affirm, that as, in the sensations, the impression is made on the nerve, and perception is effected in the brain; so, in muscular motion, volition is the act of the encephalon, and the nervous influx corresponds to the act of impression.

With regard to the seat of this nervous centre of muscular contraction, much discrepancy has arisen amongst recent physiologists. It manifestly, does not occupy the whole encephalon; as certain parts of it may be irritated, in the living animal, without exciting convulsions. Parts, again, may be removed without preventing the remainder from exciting muscular contraction when irritated. In the experiments of Flourens, the cerebral lobes were removed, yet the animals were susceptible of motion, when stimulated; and, whenever the medulla oblongata was irritated, convulsions were produced. Its seat is not, therefore, in the whole encephalon.

Rolando, of Turin, refers it to the cerebellum. He asserts that, on removing the cerebellum of living animals, without implicating any of the other parts of the encephalon, the animals preserved their sensibility and consciousness, but were deprived of the power of motion. This occurred to a greater extent in proportion to the severity of the injury inflicted on the cerebellum. If the injury was slight, the loss of power was slight; and conversely. Impressed with the resemblance between the cerebellum of birds and the galvanic apparatus of the torpedo; and taking into consideration the lamellated structure of the cerebellum, which, according to him, resembles a voltaic pile; and the results of his experiments, which showed, that the movements diminished in proportion to the injury done to the cerebellum, Rolando drew the inference, that this part of the encephalon is an electro-motive apparatus, for the secretion of a fluid analogous to the galvanic. This fluid is, according to him, transmitted along the nerves to the muscles, and excites them to contraction. The parts of the encephalon, concerned in volition, would in this view, regulate the quantity in which the motive fluid is secreted, and govern the motions; whilst the medulla oblongata which, when alone irritated, always occasions convulsions, would put the encephalic extremity of the conducting nerves in direct or indirect communication with the locomotive apparatus.

This ingenious and simple theory is, however, overthrown by the fact, mentioned by Magendie, that he is annually in the habit of exhibiting to his class animals deprived of cerebellum, which are still capable of executing very regular movements. For example, he has seen the hedge-hog and Guinea-pig, deprived not only of brain but of cerebellum, rub its nose with the paw, when a bottle of strong acetic acid was held to it; and he properly remarks, that a single positive fact of this kind is worth all the negative facts that could be adduced. He farther observes, that there could be no doubt of the entire removal of the brain in his experiments.

These experiments of Magendie are equally adverse to the hypothesis of Flourens, that the cerebellum is the *regulator* or *balancer* of the movements.

Others, again, have esteemed the encephalon to be the sole organ of volition, and have referred the nervous action, which produces the "locomotive influx," as it is termed, exclusively to the spinal marrow; and, hence, they have termed the spinal marrow and the nerves issuing from it, the "*nervous system of locomotion.*" It is manifest, however, that the encephalon must participate with the medulla spinalis in this function; inasmuch as not only does direct irritation of several parts of the former excite convulsions, but we see them frequently as a consequence of disease of the encephalon; yet, as has been remarked, there is some reason for believing, that, in the upper classes of animals, an obscure volition may be exercised for a time, even when the encephalon is separated from the body, It need scarcely be said, that we are as ignorant of the character of this influx, as we are of that of the nervous phenomena in general.

The parts of the encephalon and spinal marrow, concerned in muscular motion, are very distinct from those that receive the impressions of external bodies. The function of sensibility is comprised in the medulla oblongata and in the posterior column of the spine, whilst the encephalic organs of muscular motion appear to be the corpora striati, the thalami nervorum opticorum, at their lower part; the crura cerebri, the pons varolii, the peduncles of the cerebellum, the lateral parts of the medulla oblongata, and the anterior column of the medulla spinalis. This is proved by direct experiment, as will be seen presently; and, in addition to this, pathology furnishes us with numerous examples of their distinctness. In various cases of hemiplegia or palsy of one side of the body,—which is of an encephalic character,—we find motion almost lost, and yet the sensibility slightly or not at all affected; and, on the other hand, instances of loss of sensation have been met with, in which the power of voluntary motion has continued. The recent discoveries in the system of vertebral nerves exhibit clearly how this may happen; and that a considerable space may exist between the roots of a nerve, one of which shall be destined for sensation, the other for motion; yet both may pass out enveloped in one sheath;—the same nervous cord thus conveying the two irradiations, if they may be so termed. According to Sir Charles Bell's system, the spinal column is divided into three tracts; the anterior for motion; the posterior for sensibility; and the two are kept separate and united by the third—the column for respiration.

The experiments performed of late years,—by the French physiologists especially,—for the purpose of discovering the precise parts of the encephalon concerned in muscular motion, have attracted great and absorbing interest. We wish it could be said, that the results have been such as to afford us determinate notions on the subject.

According to those of Flourens, the cerebral lobes preside over volition, and the medulla oblongata over the locomotive influx; to the latter organ he assigns, also, sensibility. We have already seen, that the results of his experiments have been contested, and with them, of course, his deductions. The facts and arguments, which we have stated, will have shown, too, that the last proposition is alone correct—which refers sensibility to the medulla oblongata; and even it is not restricted to that organ or group of organs whichever it may be considered.

MM. Foville and Pinel Grand-Champ have affirmed, that the cerebellum is the seat of sensibility. To this conclusion they were led by the remarks they had made, in the course of their practice, that the cases of paralysis of sensibility, which fell under their notice, succeeded more especially to morbid conditions of the encephalon. In this view they conceive themselves supported by the discovery of columns in the spinal marrow, destined for particular functions; and, as the posterior column is found to be the column of sensibility, and as the cerebellum seems to be formed from this column, they think it ought to be possessed of the same functions. Professor Adelon remarks, that Willis professed a similar notion. and that he considered the cerebral lobes to be the point of departure for the movements, and the cerebellum the seat of sensibility. In his first volume, however, he had cited, more correctly, the views of Willis.—"Willis says positively," he remarks, "that the corpora striata are the seat of *perception;* the medullary mass of the brain, that of *memory* and *imagination;* the corpus callosum, that of *reflection:* and the cerebellum, the source of the *motive spirits.*" Willis, in truth, regarded the cerebellum as supplying animal spirits to the nerves of involuntary functions, as the heart, intestinal canal, &c.

The opinions of Foville and Pinel Grand-Champ are subverted by the experiments of Rolando, Flourens, and Magendie, which show, that sensation continues, notwithstanding serious injury, and even entire removal of the cerebellum.

By other physiologists, the two functions have been assigned respectively to the cineritious and medullary parts of the brain; some asserting, that the seat of sensibility is more especially in the latter, and the motive force in the former. According to Treviranus, the more medullary matter an animal has in its brain and spinal marrow, in proportion to the cineritious, the greater will be its sensibility. To this, however, M. Desmoulins properly objects, that in many animals, the spinal marrow is composed exclusively of medullary matter; and consequently they ought not only to be the most sensible of all, but to be wholly devoid of the power of motion.

Others, again, as MM. Foville and Pinel Grand-Champ have reversed the matter; assigning sensibility to the cineritious substance; and motility to the medullary.

From these conflicting opinions, it is obviously impossible to sift any thing categorical; except that we are ignorant of the special seat of these functions. A part of the discrepancy, in the results of the experiments, must be ascribed to organic differences in the animals, which were the subjects of the experiments. This was strikingly exemplified in those, instituted by Magendie, which have been described.

Similar contrariety exists in the experiments and hypotheses, regarding the particular parts of the encephalon, that are concerned in determinate movements of the body. The results of many of those are, indeed, so strange, that did they not rest on such eminent authority, they might be classed amongst the romantic.

It has been already remarked, that Rolando considered the cerebellum to be an electro-motive apparatus, producing the whole of the galvanic fluid necessary for the motions. Flourens, on the other hand, from similar experiments, independently performed, and without any knowledge of those of Rolando, affirmed it to be the regulator and balancer of the locomotive movements; and he asserted, that, when removed from an animal, it could neither maintain the erect attitude, nor execute any movement of locomotion; nor, although possessing all its sensations, could it fly from the danger it saw menacing it. The same view has been advocated by Bouillaud, who has detailed eighteen experiments, in which he cauterized the cerebellum, and found that, in all, the functions of equilibration and progression were disordered.

The experiments of Magendie, on this subject, are pregnant with important novelty. We have already referred to those that concern the cerebral hemispheres and cerebellum, as the encephalic organs of the general movements, in the mode suggested by Rolando and Flourens, and others. He affirms, in addition, "that there exist, in the brain, four spontaneous impulses or forces, which are situated at the extremity of two lines, cutting each other at right angles; the one impelling forwards; the second backwards; the third from right to left, causing the body to rotate; and the fourth from left to right, occasioning a similar movement of rotation." The first of these impulses he fixes in the cerebellum and medulla oblongata; the second in the corpora striata; and the third and fourth in each of the peduncles of the cerebellum.

1. *Forward Impulse.*—It has often been observed by those who have made experiments on the cerebellum, that injuries of that organ cause the animals to recoil, manifestly against their will. Magendie asserts, that he has frequently seen animals, wounded in the cerebellum, make an attempt to advance, but be immediately compelled to run back; and he says, that he kept a duck for eight days, the greater part of whose cerebellum he had removed, which did not move forwards during the whole of that time, except when placed upon water. Pigeons, into whose cerebella he thrust pins, constantly walked, and flew backwards, for more than a month afterwards. Hence, he concludes, that there exists, either in the cerebellum or medulla oblongata, a force of impulsion, which tends to cause animals to go forward.

Magendie thinks it not improbable but that this force exists in man; and he states, that Dr. Laurent, of Versailles, exhibited to him, and to the *Académie Royale de Médecine*, a young girl, who, in the attacks of a nervous disease, was obliged to recoil so rapidly as to be incapable of avoiding bodies or pits behind her; and was, consequently, exposed to serious falls and bruises. This force, he affirms, only exists in the mammalia and in birds;—certain fish and reptiles, on which he experimented, appearing to be unaffected by the entire loss of the cerebellum.

2. *Backward Impulse.*—When the corpora striata are removed, Magendie found that the animal darted forward with great rapidity; and, if stopped, still maintained the attitude of running. This was particularly remarked in young rabbits; the animal appearing to be impelled forward by an inward and irresistible power; and passing over obstacles without noticing them. These effects were not found to take place, unless the white, radiated part of the corpora striata was cut: if the gray matter was alone divided, no modification was produced in the movements. If only one of the corpora was removed, it remained master of its movements, and directed them in different ways; stopping when it chose; but, immediately after the abstraction of the other, all regulating power over the motions appeared to cease, and it was irresistibly impelled forwards.

In the disease of the horse, called, by the French, *immobilité*, the animal is often capable of walking, trotting, and galloping forward with rapidity; but he does not back; and frequently it is impracticable to arrest his progressive motion. Magendie asserts, that he has opened several horses which died in this condition; and that he found, in all, a collection of fluid in the lateral ventricles, which had produced a morbid change on the surface of the corpora striata, and must have exerted a degree of compression on them.

Similar pathological cases appear to occur in man. Magendie relates the case of a person, who became melancholic, and lost all power over his movements; continually executing the most irregular and fantastic antics; and frequently compelled to walk exclusively forwards or backwards until stopped by some obstacle. In this case, however, the patient got well; and accordingly there was no opportunity for investigating the encephalic cause. M. Itard, also, describes two cases, in which the patients were impelled, in paroxysms, to run straight forward, without the power of changing their course, even when a river or precipice was immediately before them.

A case is related by M. Piédagnel, in the third volume of the *Journal de Physiologie*, which is more to the purpose than those just mentioned, inasmuch as an opportunity occurred for *post mortem* inquiry. The subject of it was, also, irresistibly impelled to constant motion. "At the time of the greatest stupor," says M. Piédagnel, "he suddenly arose; walked about in an agitated manner; made several turns in his chamber, and did not stop until he was fatigued. On another occasion the room did not satisfy him; he went out, and walked as long as his strength would permit. He remained out about two hours, and was brought back on a litter." M. Piédagnel adds, "that he seemed impelled by an insurmountable force," which kept him in motion, until his powers failed him. On dissection, several tubercles were found in the right cerebral hemisphere, especially at its anterior part; and at the side of the corpora striata. These had produced considerable morbid changes in this hemisphere; and had, at the same time, greatly depressed the left.

From these facts, Magendie infers it to be extremely probable, that, in the mammalia and in man, a force of impulsion always exists, which tends to impel them backwards, and which is, consequently, the antagonist to the force seated in the cerebellum.

3. *Lateral Impulse.*—Again, if the peduncles of the cerebellum—the crura cerebelli—be divided in a living animal, it immediately begins to turn round, as if impelled by some considerable force. The rotation or circumgyration is made in the direction of the divided peduncle; and, at times, with such rapidity, that the animal makes as many as sixty revolutions in a minute. The same kind of effect is produced by any vertical section of the cerebellum, which implicates, from before to behind, the whole substance of the medullary arch, formed by that organ above the fourth ventricle, (See Fig. 13,) but the movement is more rapid, the nearer the section is to the origin of the peduncles; in other words, to their point of junction with the pons varolii.

Magendie affirms, that he has seen this movement continue for eight days without stopping, and, apparently, without suffering. When any impediment was placed in the way, the motion was arrested; and, under such circumstances, the animal frequently remained with its paws in the air, and ate in this attitude. What he conceives to have been one of his most singular experiments was, the effect of the division of the cerebellum into two lateral and equal halves: the animal appeared to be alternately impelled to the right and left, without retaining any fixed position: if he made a turn or two on one side, he soon changed his motion and made as many on the other.

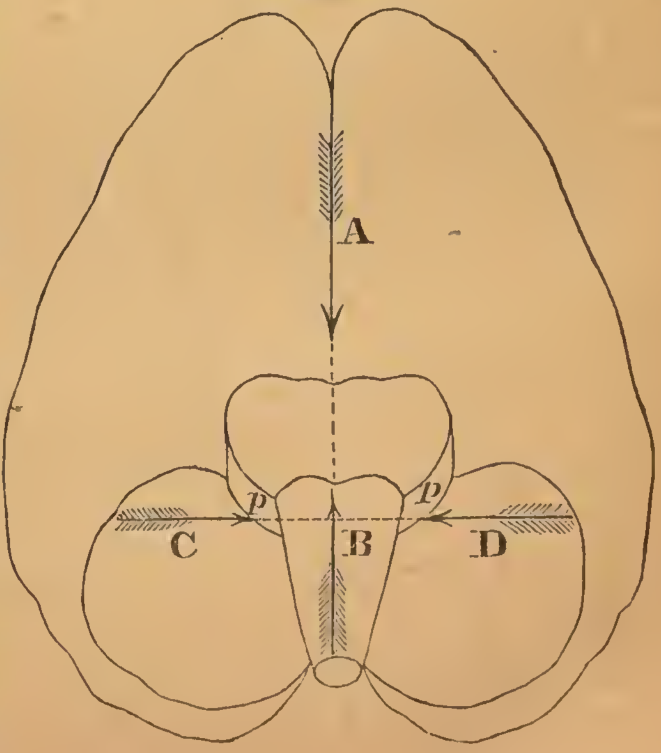
M. Serres—who is well known as a writer on the comparative anatomy of the brain, and must have had unusual opportunities for observation at the Hospital *La Pitié*, to which he is attached—gives the case of an apoplectic, who presented, amongst other symptoms, the singular phenomenon of turning round, like the animals in the experiments just described; and, on dissection, an apoplectic effusion was found in this part of the encephalon.

On dividing the pons varolii vertically, from before to behind, Magendie found, that the same rotatory movement was produced: when the section was to the left of the median line, the rotation was to the left, and conversely; but he could never succeed in making the section accurately on the median line.

From these facts, he concludes, that there are two forces, which are equilibrious by passing across the circle formed by the pons varolii and cerebellum. To put this beyond all question, he cut one peduncle, when the animal immediately rolled in one direction; but on cutting the other, or the one on the opposite side, the movement ceased, and the animal lost the power of keeping itself erect, and of walking.

From the results of all his experiments, Magendie infers, that an animal is a kind of automatic machine, wound up for the performance of certain motions, but incapable of producing any other. The marginal figure of the base of the brain, will explain, more directly, the impulses described by that physiologist. The corpora striata are situated in each hemisphere, but their united impulses may be represented by the arrow A; the impulse, seated in the cerebellum, by the arrow B; and those in each peduncle of the cerebellum, *p p*, by the arrows C and D respectively. When the impulse backwards is from any cause destroyed, the animal is given up to the forward

Fig. 61.



impulse, or to that represented by the arrow B, and *vice versa*. In like manner, the destruction of one lateral impulse leaves the other without an antagonist, and the animal moves in the direction of the arrow placed over the seat of the impulsion that remains. In a state of health, all these impulsions being nicely antagonized, they are subjected to the influence of volition; but in disease they may, as we have seen, be so modified, as to be entirely withdrawn from its control.

The four general movements are not the only ones, excited by particular injuries done to the nervous system. Magendie states, that a circular movement, to the right or left, similar to that of horses in a circus, was caused by the division of the medulla oblongata, to the outer side of the corpora pyramidalia anteriora. When the section was made on the right side, the animal turned, in this fashion, to the right; and to the left, if it was made on that side.

Pathology has, likewise, indicated the brain as the seat of different bodily movements. Diseases of the encephalon have been found not only to cause irregular movements or convulsions, but, also, paralysis of a part of the body, leaving the rest untouched. Hence it has been concluded, that every motion of every part has its fixed point in some portion of the brain.

The ancients were well aware, that in cases of hemiplegia, the encephalic cause of the affection is found in the opposite hemisphere. Attempts have accordingly been made to decide upon the precise part of the encephalon, where the decussation takes place. Many have conceived the commissures to be the parts; but the greater number, perhaps, have referred it to the corpora pyramidalia. These, the researches of Gall and Spurzheim had pointed out, as decussating at the anterior surface of the marrow, and as being apparently continuous with the radiated fibres of the corpora striata; and an opinion has prevailed, that the paralysis is of the same side as the encephalic affection or of the opposite, according as the affected part of the brain is a continuation of fasciculi, which do not decussate—of the corpora olivaria for example—or of the corpora pyramidalia, which do. Serres, however, affirms, that affections of the cerebellum, pons varolii, and the tubercula quadrigemina, exert their effects upon the opposite side of the body; and he supports his opinion by pathological cases and direct experiment. Evidence of the latter kind has been afforded by Magendie, which completely overthrows the idea that the decussation occurs at the corpora pyramidalia. He divided one pyramid from the fourth ventricle; yet no sensible effect was produced on the movements; certainly there was no paralysis, either on the affected side or on the opposite one: more than this, he divided both pyramids about the middle, and no apparent derangement occurred in the motions; —a slight difficulty in progression being alone observable.

The section of the posterior pyramids, or corpora restiformia, was equally devoid of perceptible influence on the general movements; and to cause paralysis of one-half the body, it was necessary to divide the half of the medulla oblongata, and then the corresponding side became—not immovable, for it was affected by irregular movements, and not insensible, for the animal moved its limbs when they were pinched,—but incapable of executing the determinations of the will.

So far, then, as these experiments go, they disprove the idea of decussation in the medulla oblongata. Its seat must, consequently, be looked for elsewhere, and probably in the commissures.

The result of the examination of morbid cases, again, has induced some physiologists to proceed still farther in their location of the encephalic organs of muscular motion; and to attempt some explanation of paraplegia, or of those cases, in which one-half the body, under the transverse bisection, is paralyzed. MM. Serres, Foville, and Pinel Grand-Champ assert, that the anterior radiated portion of the corpora striata presides over the movements of the lower limbs; and the optic thalamus over those of the upper; and that according as the extravasation of blood, in a case of apoplexy, occurs in one of these parts, or in all, the paralysis is confined to the lower or to the upper limbs, or extends to the whole body. In 1768, Saucerotte presented a prize memoir to the *Académie Royale de Chirurgie*, of Paris, in which a similar view was expressed. He had concluded, from experiments, that affections of the anterior parts of the encephalon paralyzed the lower limbs, whilst those of the posterior parts paralyzed the upper. M. Chopart,—in a prize essay, crowned in 1769, and contained in the same volume with the last—the fourth of the *Prix de l' Académie Royale de Chirurgie*—refers to the result of some experiments by M. Petit, of Namur, which appeared to show, that paralysis of the opposite half of the body was not induced by injury of the cerebral hemisphere, unless the corpora striata were cut or removed.

The experiments of Saucerotte were repeated by M. Foville, and are detailed in a memoir, crowned by the *Académie Royale de Médecine*, of Paris, in 1826. They were attended with like results. In cats and rabbits, he cauterized, in some, the anterior part of the encephalon; in others, the posterior part; and in every one of the former, paralysis of the posterior, in the latter, of the anterior extremities succeeded. Having, in one animal, mutilated the whole of the right hemisphere, and only the anterior part of the left, he found, that the animal was paralyzed in the hinder extremities, and in the paw of the left fore-leg, but that the paw of the right remained active.

Lastly, the motions of the tongue, or of articulation, are sometimes alone affected in apoplexy. The seat of this variety of muscular motion has been attempted to be deduced from pathological facts. Foville places it in the cornu ammonis and temporal lobe; and Bouillaud in the anterior lobe of the brain, in the medullary substance; the cineritious being concerned, he conceives, in the intellectual part of speech.

It is sufficiently obvious, from the whole of the preceding detail, that the mind must still remain in doubt, regarding the precise part of the encephalon engaged in the functions of muscular motion. The experiments of Magendie are, perhaps, more than any of the others, entitled to consideration. They appear to have been instituted without any particular bias; to subserve no particular theory; and they are supported by pathological facts furnished by others. M. Magendie is, withal, an accurate and practised experimenter, and one to whom physiology has been largely indebted. His vivisections have been more numerous, perhaps, than those of any other individual. His investigations, however, on this subject clearly show, that owing to the different structures of animals, we cannot draw as extensive analogical deductions from comparative anatomy and physiology as might have been anticipated. The greatest source of discrepancy, indeed, between his experiments and those of M M. Rolando and Flourens, appears to have arisen in the employment of different animals. Where the same animals were the subjects of the vivisections, the results were in accordance. The experiments demand careful repetition, accompanied by watchful and assiduous observation of pathological phenomena; and, until this is effected, we can, perhaps, scarcely feel justified in deducing, from all these experiments and investigations, more than the general propositions, regarding the influence of the cerebro-spinal axis on muscular motion, which we have already enunciated.

The nerves, it has been shown, are the agents for conducting the locomotive influence to the muscles. At one time, it was universally believed, that the same nerve conveys both sensation and volition; but the pathological cases, that not unfrequently occurred, in which either sensation or voluntary motion was lost, without the other being necessarily implicated, and of late years, the beautiful additions to our knowledge of the spinal nerves, for which we are mainly indebted to Sir Charles Bell and Magendie, have satisfied the most sceptical, that there are separate nerves for the two functions, although they may be enveloped in the same neurilemma, or nervous sheath; or, in other words, may constitute the same nervous cord. We have more than once asserted, that the posterior column of the spine, with the nerves proceeding from it, is chiefly concerned in the function of sensibility, and that the anterior column, and the nerves connected with it, are inservient to muscular motion; whilst a third column intervenes, which, in the opinion of Sir Charles Bell, is the source of all the respiratory nerves and of the various movements connected with respiration and expression. It is proper here again, to observe, that although these two distinguished physiologists agree in their assignment of function to the anterior and posterior columns of the spinal marrow, Bellingeri has deduced very different inferences from the same experiments.

He asserts, that having divided, on living animals, either the anterior roots of the spinal nerves, and the anterior column of the medulla spinalis, or the posterior roots of these nerves, and the posterior column of the marrow, he did not occasion, in the former case, paralysis of motion, and in the latter, of sensation; but only, in the one, the loss of all the movements of flexion; and in the other, of those of extension. In his view, the brain and its prolongations, as the crura cerebri, corpora pyramidalia, the anterior column of the spinal marrow, and the nerves connected with it, preside over the movements of flexion; and, on the contrary, the cerebellum and its extensions, as the posterior column of the medulla spinalis, and the nerves connected with it, preside over the movements of extension: he infers, in other words, that there is an *antagonism* between these sets of nerves.

The *prima facie* evidence is against the accuracy of Bellingeri's experiments. The weight of authority in opposition to him is, in the first place, preponderant; and in the second place, it seems highly improbable, that distinct nerves should be employed for the same kind of muscular action. Moreover, in some experiments on the frog, Professor Müller of Bonn, has established the correctness of the views of Bell. It seems, that the different physiologists, who engaged in the inquiry before he did, employed warm-blooded animals in their experiments, and he imagines, that the pain, resulting from the necessarily extensive wounds, may have had such an effect on the nervous system as to modify, and perhaps even counteract, the results. Müller employed the frog, whose sensibility is less acute, and its tenacity of life greater. If the spinal marrow of this animal be exposed, and the posterior roots of the nerves of the lower extremities be cut, not the least motion is perceptible when the divided roots are excited by mechanical means, or by galvanism. But if the anterior roots be touched, the most active movements are instantly observed. The movements may also be excited by the galvanic pile. These experiments, Müller remarks, are so readily made, and the evidence they afford is so palpable, that they leave no doubt as to the correctness of the views of Sir Charles Bell.

In the ordinary cases of the action of a voluntary muscle, the nervous influence, emanating from some part of the cerebro-spinal axis, under the guidance of volition, proceeds along the nerves, with the rapidity of lightning, and excites the muscle to contraction. The muscle, which was before smooth, becomes rugose, the belly more tumid, the ends approximate, and the whole organ is rendered thicker, firmer, and shorter.

With regard to the precise degree of contraction or shortening, which a muscle experiences, some difference of sentiment has prevailed. Bernouilli and Keill estimated it at one-third of the length;

and Dumas carried it still higher. It must, of course, be proportionate to the length of the fibres,—being greater the longer the fibres. It has, also, been a subject of experiment and of speculation, whether the bulk and the specific gravity of a muscle are augmented during its contraction. Borelli and Sir Anthony Carlisle affirm, that the size of the muscle is increased. In the experiments of the latter, the arm was immersed in a jar of water, with which a barometrical tube was connected; and when the muscles were made to contract strongly, the level of the water in the tube was raised. Glisson, however, from the same experiment, deduced opposite conclusions: Swammerdam and Ermann appear to be of his opinion, and Sir Gilbert Blane, Mr. Mayo, Barzellotti and MM. Dumas and Prévost, during the most careful experiments, could see no variation in the level of the fluid; and, consequently, do not believe, that the size of a muscle is modified by its contraction. Sir Gilbert Blane inclosed a living eel in a glass vessel filled with water, the neck of which was drawn out into a fine tube; then, by means of a wire, introduced into the vessel, he irritated the tail of the animal, so as to excite strong contraction during which he noticed, that the water in the vessel remained entirely stationary. He, likewise, compared the two sides of a fish, one of which had been crimped, and thus brought into a state of strong contraction; the other left in its natural condition: their specific gravity was precisely the same.

The experiment of Barzellotti was the following.—He suspended, in a glass vessel, the posterior half of a frog, filled the jar with water, and closed it with a stopper, traversed by a narrow, graduated tube. The muscle was then made to contract by means of galvanism, but in no case was the level of the liquid in the tube changed.

It may, then, be concluded, that the bulk of a muscle is not greater when contracted than when relaxed.

During contraction, the muscle is sometimes so rigid and elastic as to be capable of vibration when struck. The ordinary firm state is well exhibited by the masseter, when the jaws are forcibly closed, and some men possess the power of producing sonorous vibrations by striking the contracted biceps with a metallic rod.

It has been a matter of dispute, whether the quantity of blood, circulating in a muscle, is diminished during its contraction. At one time, it was universally believed, that such diminution existed, and accounted for the diminished size of the muscle during contraction. This last allegation we have already shown to be inaccurate; and no correct deduction can, consequently, be drawn from it. Sir Anthony Carlisle adopted the opinion, that the muscles become pale during contraction; but he offers no proof of it. The probability is, that he implicitly obeyed, in this respect, the dicta of his precursors, without observing the incongruity of such a supposition with his idea, that the absolute size of the muscle is augmented during contraction. The truth is, we have no evidence, that the colour of a muscle, or the quantity of blood circulating in it, is at all altered during contraction. Bichat, who adopted the opinion, that the blood is forced out during this state, relies chiefly upon the fact, known to every one, that, in the operation of blood-letting from the arm, the flow of blood is augmented, by working the muscles; but the additional quantity, expelled in this case, is properly ascribed, by Dr. Bostock, to the compression of the large venous trunks, by the swelling out of the bellies of the muscles.

The prevalent belief, amongst physiologists, of the present day, is, that there is no change of colour in the muscle during contraction.

When the extremities of a muscle are made to approximate, the belly, of course, swells out, and would probably expand to such an extent, that the fasciculi, of which it is composed, would separate from each other, were it not for the cellular membrane and aponeuroses, with which they and the whole muscle are enveloped.

The phenomena, attendant upon the relaxation of a muscle, are the reverse of those, that accompany its contraction. The belly loses its rugose character, becomes soft, and the swelling subsides, the ends recede, and the organ is as it was prior to contraction. It is obvious, however, that after a part, as the arm, has been bent by the contraction of appropriate muscles, simple relaxation would not be sufficient to restore it to its original position; for although the relaxation of a muscle has been regarded, by Bichat and others, to be, in part at least, an active effort, and to consist in something more than the mere cessation of contraction, the evidence in favour of this view is extremely feeble and unsatisfactory. The arrangement of the muscular system is, in this as in every other respect, admirable, and affords signal evidence of Omnipotent agency. The arm, as in the case selected above, has not only muscles to bend, but also to extend it; and, accordingly, when it has been bent, and it becomes necessary to extend it, the flexor muscles are relaxed and rest, whilst the extensors are thrown into action. This disposition of antagonist muscles prevails in almost every part of the frame, and will require notice presently.

Muscles are not, however, the sole agents in replacing parts. Many elastic textures exist, which, when put upon the stretch by muscular contraction, have a tendency to return to their former condition, as soon as the extending cause is removed. Of this, a good example occurs in the cartilages of prolongation, which unite the ribs to the sternum. During inspiration, these elastic bodies are extended; and, by returning upon themselves, they become active agents of expiration; tending to restore the chest to its unexpanded state.

The production of the phenomena of muscular contraction is, so far as we know, unlike any physical process with which we are acquainted. It has, therefore, been considered essentially organic and vital; and, like other operations of the kind, will, probably, ever elude our researches. Yet here, as on every obscure subject, hypotheses have been innumerable; varying according to the fashionable systems of the day, or the views of the propounder.

They who believed, that the muscular fibre is hollow, or vesicular, ascribed its contraction to distention, by the influx of the animal spirits, or of the blood; and relaxation to the withdrawal of those fluids. Such were the hypotheses of Borelli, Stuart, and others. Independently, however, of the great objection to these views,—that we have no positive evidence of the existence of rhomboidal or other vesicles, or of the tubular form of the elementary fibre,—it is obvious, that the explanation is defective, inasmuch as we have still to look to the cause, which produces this mechanical influence. Again, how are we to account, under this hypothesis, for the surprising efforts of strength executed by muscles? The mechanical influx of animal or other spirits—granting for a moment their existence—might develope a certain degree of force; but how can we conceive them able, as in the case of the muscles inserted into the foot, to develope such a force as to project the body from the ground? In all these cases, a new and occult force is generated in the brain; and this, by acting on the muscular fibre, is the grand, efficient cause of the contraction. Moreover, what an inconceivable amount of fluids would be necessary to produce the contraction of the various muscles, which are constantly in action; and what, it has been asked, becomes of these fluids when relaxation succeeds contraction? Some have affirmed, that they are absorbed by the venous radicles; others, that they run off by the tendons; and others, again, that they become neutralized in the muscle, and communicate to it the greater size it possesses, in proportion as it is more exercised. These phantasies are too abortive to require comment.

When chemical hypotheses were in fashion in medicine, physiology participated in them largely. At one time it was imagined that an effervescence was excited in the muscle by the union of two substances, one of which was of an acid, the other of an alkaline nature. Willis, Mayow, Keill, Bellini, &c. supported opinions of this kind; some ascribing the effervescence to a union of the nervous fluid with the arterial blood; others to a union of the particles of the muscular fibre with the nervous fluid; and others, to the disengagement of an elastic gas, primitively contained in the blood, and separated from it by the nervous spirits. It would, however, be unprofitable, as well as uninteresting, to repeat the different absurdities of this period—so prolific in physical obscurities. Medicine has generally kept pace with physics, and where the latter science has been dark and enigmatical, the former has been so likewise. In physiology, this is especially apparent; most of the natural philosophers of eminence having applied their doctrines in physics to the explanation of the different functions of the human frame. Newton, Leibnitz, and Descartes, were all speculative physiologists.

The discovery of electricity gave occasion to its application to the topic in question; and it was imagined, that the fibres of the muscle might be disposed in such a manner as to form a kind of battery, capable of producing contraction by its explosions; and after the discovery of galvanic electricity, Valli attempted to explain muscular contraction, by supposing, that the muscles have an arrangement similar to that of the galvanic pile.

Haller endeavoured to resolve the problem by his celebrated doctrine of *irritability*, which will engage attention hereafter. He conceived, that the muscles possess, what he calls, a *vis insita;* and that their contraction is owing to the action of this force, excited by a stimulus, which stimulus is the nervous influx directed by volition. This, it is manifest, affords us no new light on this mysterious process. It is, in fact, cutting the gordian knot. We should still have to explain the precise mode of action of this vis insita.

The hypothesis of Prochaska is entirely futile. He gratuitously presumes, as we have seen, that the minute ramifications of the arteries are everywhere connected with the ultimate muscular filaments, twining around them, and crossing them in all directions. When these vessels are rendered turgid by an influx of blood,—by passing among the filaments, he conceives they must bend the latter into a serpentine shape, and thus diminish their length, and that of the muscle likewise.

Sir Gilbert Blane, again, throws out a conjecture, deduced from those experiments, in which he found that the actual bulk of a muscle is not changed during contraction, but that it gains in thickness exactly what it loses in length—that this may be owing to the muscle being composed of particles of an oblong shape; and that when the muscle is contracted, the long diameter of the particle is removed from a perpendicular to a transverse direction. But the same objection applies to this as to other hypotheses on the subject; that it is entirely gratuitous—resting on no anatomical support whatever.

There are two views which may be esteemed as the most prevalent at the present day; the one, which considers muscular contraction to be a kind of combustion; the latter, that it is produced by electricity. The former, which was originally propounded by Girtanner, and zealously embraced by Beddoes, who was more celebrated for his enthusiasm than for the solidity of his judgment, has now but few supporters. This hypothesis supposes, that muscular contraction depends upon the combustion of the combustible elements of the muscle, hydrogen, carbon, and azote, by the oxygen of the arterial blood;—the combustion being produced by the nervous influx, which acts in the manner of an electric spark;—at least, such is the view adopted by Richerand, one of the most fanciful of physiological speculators. Of course, we have neither direct nor analogical evidence of any such combustion, which, if it existed at all, ought to be sufficient, in a short space of time, to entirely consume the organs that afford the elements. The idea is as unfounded as numerous others that have been entertained, and is worthy only of particular notice, from its being professed in one of the few works, which we possess, on physiological science.

The second hypothesis refers muscular contraction to electricity. Attention has been already directed to the electroid or galvanoid character of the nervous agency; and we have some striking examples on record of the analogous effects produced by the physical and by the vital fluid on the phenomena under consideration.

It has been long known, that when nerves and muscles are exposed in a living animal, and brought into contact, contractions or convulsions occur in the muscles. Galvani was the first to point this out. He decapitated a living frog, removed the fore-paws, and quickly skinned it. The spine was divided, so as to leave the spinal marrow communicating only with the hind extremities by means of the lumbar nerves. He then took, in one hand, one of the thighs of the animal, and the vertebral column in the other, and bent the limb until the crural muscles touched the lumbar nerves. At the moment of contact, the muscles were strongly convulsed. The experiment was repeated by Volta, Aldini, Pfaff, Humboldt and others, and with like results. Aldini observed convulsions in the muscles by the contact of those organs with nerves, not only in the same frog, but also in two different frogs. He adds, that he remarked them when he put the nerves of a frog in connexion with the muscular flesh of an ox recently killed. Humboldt made numerous experiments of this kind on frogs. He found convulsions supervene when he placed upon a dry plate of glass a posterior extremity whose crural nerves had been exposed, and touched the nerves and the muscles with a piece of raw muscular flesh, insulated at the extremity of a stick of sealing-wax. Convulsions likewise occurred, when, instead of one piece of flesh, he used three different pieces to form the chain, one of which touched the nerve, the other the thigh, and the third the two others. The experiments were repeated by Ritter with similar results, but they were only found to succeed, when the frogs were in full vital activity, especially in spring after pairing; when the animal was of sufficient size, and its preparation for the experiment had been rapidly effected.

From all these experiments it may be inferred, that parts of an animal may form galvanic chains, and produce a galvanic effect, which, independently of any mechanical excitation, may give rise to the contraction of muscles. This excitation of electricity in chains of animal parts, M. Tiedemann thinks, ought not to be esteemed a vital act. Its effects only—the contractions excited in the muscles—are dependent on the vital condition of the muscles and nerves. He considers, that the electricity, excited in chains of heterogeneous animal parts, may be modified and augmented by the organic or living forces; and that, moreover, in certain animals, organs exist, the arrangement of which is such as to excite electricity during their vital action—as in the different kinds of electrical fishes; but in some experiments, instituted by M. Edwards, the same effects, as those above referred to, were produced by touching a denuded nerve with a slender rod of silver, copper, zinc, lead, iron, gold, tin, or platina, and drawing it along the nerve for the space of from a quarter to a third of an inch. He took care to employ metals of the greatest purity, and as they were furnished him by the assayers of the mint. But it was not even necessary, that the rod should be metallic: he succeeded with glass or horn. All these metals, however, did not produce equally vigorous contractions. Iron and zinc were far less effective than the others, but no accurate scale could be formed of their respective powers.

Much difference is found to exist, when electricity is employed, according as the nerve is insulated or not; for as the muscular fibre is a good conductor of electricity, if the nerve be not insulated, the electricity is communicated to both nerve and muscle, and its effect is consequently diminished. It became, therefore, interesting to M. Edwards to discover, whether any difference would be observable, when one metal only was used, according as the nerve was insulated or not. In the experiments above referred to, the nerve was insulated by passing a strip of oiled silk beneath it. A comparison was now instituted between an animal thus prepared, and another whose nerves instead of being insulated, rested on the subjacent flesh. He made use of small rods, with which he easily excited contractions, when he drew them from above to below, along the denuded portion of nerve which was supported by the oiled silk, but he was unable to excite them, when he passed the rod along the nerve of the other animal which was not insulated. His experiments were then made on two nerves of the same animal, and he found that after having vainly attempted to produce contractions by the contact of a nerve resting upon muscle, they could still be induced if the oiled silk were had recourse to, and he was able to command their alternate appearance and disappearance, by using a non-conductor or a conductor for the support of the nerve.

Somewhat surprised at these results, M. Edwards was stimulated to the investigation,—whether some degree of contraction might not be excited by touching the uninsulated nerve, and, having remarked, that contractions were most constantly produced in the insulated nerve, by a quick and light touch, he adopted this method on an animal whose nerve was not insulated, and frequently obtained slight contractions. All his experiments on this subject seemed to prove, that, *cæteris paribus*, the muscular contractions, produced by the contact of a solid body with a nerve, are much less considerable, or even wholly wanting, when the nerve, in place of being insulated is in communication with a good conductor, and it would seem to follow, as a legitimate conclusion, that these contractions are dependent on electricity; facts, which it is well to bear in mind, in all experiments on animals where feeble electrical influences are employed.

Galvanic electricity, we shall see hereafter, is one of the great tests of muscular irritability, and is capable of occasioning contraction, for some time after the death of the animal, as well as of maintaining, for a time, many of the phenomena peculiar to life. Hence the reason, why muscular contraction, which is provoked by this nervous, electroid fluid, has been regarded as an electrical phenomenon. Much discrepancy has, however, arisen amongst the partisans of this opinion, regarding its *modus operandi*. Rolando, we have seen, assimilates the cerebellum to an electro-motive apparatus, which furnishes the fluid, that excites the muscles to contraction. Some have compared the spinal column to a voltaic pile, and have supposed the contraction of a muscle to be owing to an electric or galvanic shock. The views of MM. Dumas and Prévost are amongst the most recent and novel. By a microscope, magnifying ten or twelve diameters, they first of all examined the manner in which the nerves are arranged in a muscle; and found, as has been already observed, that their ramifications always entered the muscle in a direction perpendicular to its fibres. They satisfied themselves, that none of the nerves really terminate in the muscle; but that the final ramifications embrace the fibres, like a noose, and return to the trunk, that furnishes them, or to one in its vicinity; the nerve setting out from the anterior column of the spinal marrow, and returning to the posterior. On farther examining the muscles, at the time of their contraction, the parallel fibres, composing them, were found, by the microscope, to bend in a zig-zag manner, and to exhibit a number of regular undulations; such flexions forming angles, which varied according to the degree of contraction, but were never under fifty degrees. The flexions, too, always occurred at the same parts of the fibre, and to them the shortening of the muscle was owing, as MM. Dumas and Prévost proved by calculating the angles.

The angular points were always found to correspond to the parts, where the small nervous filaments enter or pass from the muscles. They therefore believed, that these filaments, by their approximation, induce contraction of the muscular fibre; and this approximation they have ascribed to a galvanic current running through them; which as the fibres are parallel and very near each other, they have thought, ought to cause them to attract each other, according to the law laid down by Ampère, that two currents attract each other when they move in the same direction. The living muscles are, consequently, regarded by them as galvanometers, and galvanometers of an extremely sensible kind, on account of the very minute distance and tenuity of the nervous filaments.

They, moreover, affirm that, by anatomical arrangement, the nerve is fixed in the muscle in the very position required for the proper performance of its function; and they esteem the fatty matter, which envelopes the nervous fibres, and which was discovered by Vauquelin, as a means of insulation, to prevent the electric fluid from passing from one of the fibres to the other.'

Soon after hearing of Ampère's discovery of the attraction of electrical currents, it occurred to Dr. Roget, that it might be possible to render the attraction between the successive and parallel turns of heliacal or spiral wires very sensible, if the wires were sufficiently flexible and elastic: and, with the assistance of Mr. Faraday, his conjecture was put to the test of experiment, in the laboratory of the Royal Institution of London. A slender harpsichord-wire bent into a helix, being placed in the voltaic circuit, instantly shortened itself whenever the electric stream was sent through it: but recovered its former dimensions the moment the current was intermitted. From this experiment it was supposed, that possibly some analogy might hereafter be found to exist between the phenomenon and the contraction of muscular fibres.

The views of Prévost and Dumas have been altogether denied by M. Raspail, inasmuch as it is impossible, he says, to distinguish, by the best miscroscope, the ultimate muscular fibre from the small nervous fibrils by which those gentlemen consider them to be surrounded loopwise. He farther affirms, that the zig-zag form is the necessary result of the method in which they performed their experiments, and is produced by the muscular fibre adhering to the glass on which it was placed. His own idea, founded on numerous observations, is, that the contraction of the fibre in length is always occasioned by its extension in breadth under the influence of the vital principle. Independently, however, of Raspail's objection, the circumstance, that, in this mode of viewing the subject, the muscle itself is passive, and the nerve alone active, is a weighty stumbling-block in the way of the views of both MM. Prévost and Dumas, and Dr. Roget.

With regard to the hypothesis, which ascribes muscular contractility to the chemical composition of the fibre, or that which maintains, that the property is dependent upon the mechanical structure of the fibre, they are undeserving of citation, notwithstanding the respectability of the individuals, who have written and experimented on the subject. They merely seem to show, that here, as in every case, a certain chemical and mechanical constitution is necessary, in order that the vital operation, peculiar to the part, may be developed.

But not only is it necessary, that the muscle shall possess a proper physical organization, it must, likewise, be endowed with one, that is essentially vital—in other words, with *irritability*. The cause of the ordinary contraction of muscles is, doubtless, the nervous influx, but if we alter the condition of the muscle, by tying the vessels that supply it with blood, although the nervous influx may be properly transmitted to it, there will be no contraction. We, moreover, find, that after a muscle has acted for some time it becomes fatigued, notwithstanding volition may regularly direct the nervous influx to it; and that it requires repose, before it is again capable of executing its functions.

In the upper classes of animals, contractility remains for some time after dissolution; in the lower classes, especially in the amphibia, the period during which it is evinced, on the application of appropriate stimuli, is much greater. One of the most interesting of the many experiments that have been made on the bodies of criminals recently deceased, for the purpose of exhibiting the effects of galvanism on muscular irritability, is detailed by Dr. Ure. The subject was a murderer, named Clydesdale, a middle-sized athletic man, about thirty years of age. He was suspended from the gallows nearly an hour, and made no convulsive struggle after he dropped. He was taken to the theatre of the Glasgow University in about ten minutes after he was cut down. His face had a perfectly natural aspect, being neither livid nor tumefied: and there was no dislocation of the neck.

In the first experiment, a large incision was made into the nape of the neck, close below the occiput, and the spinal marrow was brought into view. A considerable incision was made, at the same time, into the left hip, through the glutæus maximus muscle, so as to expose the sciatic nerve, and a small cut was made in the heel, from neither of which any blood flowed. A pointed rod, connected with one end of a galvanic battery, of two hundred and seventy pairs of four-inch plates, was now placed in contact with the spinal marrow, whilst the other rod was applied to the sciatic nerve. Every muscle of the body was immediately agitated with convulsive movements, resembling a violent shuddering from cold. The left side was most powerfully convulsed at each renewal of the electric contact. On removing the second rod from the hip to the heel, the knee being previously bent, the leg was thrown out with such violence, as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

In the next experiment, the left phrenic nerve was exposed at the outer edge of the sterno-thyroideus muscle. As this nerve is distributed to the diaphragm, and communicates with the heart through the pneumo-gastric nerves, it was expected that, by transmitting the galvanic fluid along it, the respiratory process might be renewed. Accordingly, a small incision having been made under the cartilage of the seventh rib, the point of one rod was brought into contact with the great head of the diaphragm, whilst the point of the other was applied to the phrenic nerve in the neck. The diaphragm, which is a main agent in respiration, was instantly contracted, but with less force than was expected. "Satisfied," says Dr. Ure, "from ample experience on the living body, that more powerful effects can be produced in galvanic excitation, by leaving the extreme communicating rods in close contact with the parts to be operated on, while the electric chain or circuit is completed, by running the end of the wires along the top of the plates in the last trough of either pole, the other wire being steadily immersed in the last cell of the opposite pole, I had immediate recourse to this method. The success of it was truly wonderful. Full, nay laborious breathing, instantly commenced. The chest heaved and fell; the belly was protruded and again collapsed, with the relaxing and retiring diaphragm. This process was continued without interruption, as long as I continued the electric discharges.

In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was perhaps the most striking ever made with a philosophical apparatus. Let it also be remembered, that for full half an hour before this period, the body had been well nigh drained of its blood, and the spinal marrow severely lacerated. No pulsation could be perceived, meanwhile, at the heart or wrist; but it may be supposed, that, but for the evacuation of the blood,—the essential stimulus of that organ,—this phenomenon might also have occurred."

In a third experiment, the supra-orbital nerve was laid bare in the forehead. The one conducting rod being applied to it, and the other to the heel, most extraordinary grimaces were exhibited. Every muscle in the face was simultaneously thrown into fearful action. "Rage, horror, despair, anguish, and ghastly smiles, united their hideous expression in the murderer's face, surpassing far the wildest representation of a Fuseli or a Kean." At this period, several of the spectators were forced to leave the room from terror or sickness, and one gentleman fainted.

The last experiment consisted in transmitting the electric power from the spinal marrow to the ulnar nerve, as it passes by the internal condyle at the elbow, when the fingers moved nimbly, like those of a violin performer; and an assistant, who tried to close the fist, found the hand to open forcibly in spite of every effort to prevent it. When the one rod was applied to a slight incision in the tip of the forefinger, the fist being previously clenched, that finger was instantly extended; and from the convulsive agitation of the arm, he seemed to point to the different spectators, some of whom thought he had come to life. The experiments of Dr. Ure have been several times repeated, in this country, on the bodies of criminals, and with analogous results.

What important reflections are suggested by the perusal of such cases! The strict resemblance between the galvanic and the nervous fluids, and the absorbing idea, to the philanthropist, that galvanism may be found successful in resuscitating the apparently dead, in cases where other means would probably fail! Unfortunately it can rarely happen, that the means will be at hand, and can, consequently, be available. It must, however, be borne in mind, that, in the case just narrated, many of the effects were produced, *two hours* after respiration had been finally arrested.

An experiment, described by Dr. George Fordyce, signally exhibits the power of the contractility, which is resident in the tissue. He slightly scratched, with a needle, the inside of a heart removed from the body, when it contracted so strongly as to force the point of the needle deep into its substance. This experiment has been often cited, for the purpose of showing, that the mechanical effect, in such cases, is infinitely greater than the mechanical cause producing it; and hence, as we have endeavoured already to show, that all mechanical explanations must be insufficient to account for the phenomena of muscular contractions: we are compelled to infer, that a new force must always be generated.

Between twenty and thirty years ago, a cause was tried before the Court of Exchequer in England, in which a better knowledge of the properties of muscle might have led to a different result. According to the English law, where a man marries a woman, seised of an estate of inheritance, and has, by her, issue born alive, which was capable of inheriting her estate; in such case he shall, on the death of his wife, hold the lands for his life, as *tenant by the courtesy* of England. It has, consequently, been a point of moment for the husband to show that the child was born *alive:* and the law authorities have, with singular infelicity, attempted to define what shall be regarded evidences of this condition. According to Blackstone, "it must be born alive. Some have had a notion that it must be heard to cry, but that is a mistake. Crying, indeed, is the strongest evidence of its being born alive, but it is not the *only* evidence." According to Coke, "if it be born alive it is sufficient, though it be not heard to cry, for peradventure it may be born dumb.* It must be proved that the issue was alive; for *mortuus exitus non est exitus:* so as the crying is but a proof that the child was born alive, and so is motion, stirring, and the like." This latitudinarian definition has given occasion to most erroneous decisions, as in the trial alluded to, in which the jury agreed that the child was born alive; because, although, when immersed in a warm bath, immediately after birth, it did not "cry or move, or show any symptoms of life;" yet, according to the testimony of two females,—the nurse and the cook,—there twice appeared a twitching and tremulous motion of the lips; and this was sufficient to make it fall under Lord Coke's definition.

It is manifest, that, granting such motion to have actually occurred, it was of itself totally insufficient to establish the existence of vitality. We have seen, that on the application of stimuli, the muscles of a body may be thrown into contraction for *two hours* after the cessation of respiration. Instead, therefore, of referring the irritability to the existence, at the time, of the vital principle; it must be regarded simply as an evidence, that the parts have previously and recently formed part of a living system.

* It need scarcely be said, that the deaf-dumb cry at the moment of birth the same as other children. The natural cry is effected by them as well as by the infant that possesses all its senses. It is the *acquired* voice, alone, which they are incapable of attaining.

The contraction of a muscle is followed by its *relaxation*;—the fibres returning to their former parallel condition. This appears to be a passive state; and to result from the suppression of the nervous influx by the will;—in other words, to be produced by the simple cessation of contraction. Some have, however, regarded both states to be active, but without any proof. Barthez maintains, that the relaxation of the muscle is produced by a nervous action the reverse of that which occasions its contraction; the will relaxing the muscles as well as contracting them. The muscle is the only part susceptible of contraction. The tendon conveys the force, developed by it, passively to the lever, which has to be moved.

Lastly, a sensation instructs the mind that a muscle has contracted, and this has given rise to the notion of a *muscular sense*, and a *sensation of motion*:—the Müskelsinn or Bewegungssinn or *muscular sense* of Gruithuisen, Lenhossek, Brown, Bell, and other writers. It appears to be an internal sensation, produced by the muscle pressing on the sensible parts surrounding it; which parts convey the sensation to the brain.

It is by this muscular sense that the brain learns to adapt the effort to the effect to be produced. Without it no precision could exist in the movements of the muscles, and every manual effort—whether of the artist or the mechanic—would be confused and disorderly. The step, too, would be unsteady and insecure. "In chewing our food," says Dr. A. Combe, "in turning the eyes towards an object looked at, in raising the hand to the mouth, and, in fact, in every variety of muscular movement which we perform, we are guided by the muscular sense in proportioning the effect to the resistance to be overcome; and where this harmony is destroyed by disease, the extent of the service rendered us becomes more apparent. The shake of the arm and hand which we see in drunkards, and their consequent incapability of carrying the morsel directly to the mouth, are examples of what would be of daily occurrence, unless we were directed and assisted by a muscular sense."

The *force* or *intensity of muscular contraction* is dependent upon two causes;—the physical condition of the muscle, and the energy of the brain. A muscle, which is composed of large, firm fibres, will contract,—the energy of the brain being equal,—more forcibly than one with delicate, loose fibres. Volition generally determines the degree of power developed by the voluntary motions; and is accurately regulated so as to raise a weight of one pound or of one hundred. Again, we notice astonishing efforts of strength in those that are labouring, at the time, under strong cerebral excitement; under mania, rage, delirium, &c. In such cases, the delicate muscles of the female are capable of contracting with a force far transcending that of the healthy male. The power of muscular contraction is, therefore, in a compound ratio with the strength of the organization of the muscle, and the degree of excitation of the brain. Where both are considerable, the feats of strength surpass belief; and where both are small, the results are insignificant.

The extensors of the knee and foot occasionally contract with so much violence, as to fracture the patella and the tendo-achilles, respectively. The force, developed in the calf of the leg, must be great, when a person stands on tiptoe with a burden on his head or shoulders; or when he projects his body from the soil, as in leaping. Rudolphi asserts, that he has seen a horse, which fractured its under-jaw by biting a piece of iron.

We have a number of feats of surprising strength on record: several of which are contained in the 'Letters on Natural Magic' by Sir David Brewster: of these, the cases of John Charles Van Eckeberg, who travelled through Europe under the appellation of Samson, and of Thomas Topham, are the most authentic and extraordinary. Dr. Desaguliers saw Topham, by the strength of his fingers, roll up a very strong and large pewter dish. He broke seven or eight short and strong pieces of tobacco pipe with the force of his middle finger, having laid them on his first and third finger. Having thrust under his garter the bowl of a strong tobacco pipe, his legs being bent, he broke it to pieces by the tendons of his hams without altering the flexure of his knee. He broke another such bowl between his first and second finger, by pressing his fingers together sideways. He lifted a table six feet long—which had half a hundred weight hanging at the end of it—with his teeth, and held it in a horizontal position for a considerable time, the feet of the table resting against his knees. He took an iron kitchen poker, about a yard long and three inches in circumference, and, holding it on his right hand, he struck upon his bare left arm, between the elbow and wrist, till he bent the poker nearly to a right angle. He took such another poker, and, holding the ends of it in his hands, and the middle against the back of his neck, he brought both ends of it together before him; and afterwards pulled it nearly straight again. He broke a rope, about two inches in circumference, which was in part wound about a cylinder of four inches in diameter, having fastened the other end of it to straps that went over his shoulders. Lastly, he lifted a rolling-stone, eight hundred pounds in weight, with his hands only, standing in a frame above it, and taking hold of a chain that was fastened to it.

That much depends upon physical organization, as regards the force of muscular contraction, is evinced by the fact of the great difference in this respect in the various races of mankind. On our own continent, numerous opportunities have occurred for witnessing the inferiority, in strength, of the aborigines to the white settlers.

Péron took with him, in his voyage round the world, one of Regnier's dynamometers, which indicates the relative force of men and animals. He directed his attention to the strength of the arms and of the loins, making trial on several individuals of different nations; viz. twelve natives of Van Diemen's land, seventeen of New Holland, fifty-six of the island of Timor, seventeen French-men, belonging to the expedition, and fourteen Englishmen in the colony of New South Wales. The following was the mean result.

	Strength — Of the arms, *kilogrammes*.*	Strength — Of the loins, *myriagrammes*.
1. Van Diemen's land,	50.6	
2. New Holland,	50.8	10.2
3. Timor,	58.7	11.6
4. French,	69.2	15.2
5. English,	71.4	16.3

The highest numbers, in the first and second divisions, were respectively 60 and 62; the lowest, in the fifth, 63; and the highest 83, for the strength of the arms. In the power of the loins, the highest amongst the New Hollanders was 13; the lowest of the English 12.7.

The force of muscular contraction is, also, largely increased by the proper exercise of the muscles. Hence the utility of the ancient gymnasia. In early times, muscular energy commanded respect and admiration. It was regarded as the safeguard of families, and the protection of nations: and it was esteemed a matter of national policy to encourage its acquisition. In modern times, the invention of gunpowder having altered the system of warfare, and given to agility the superiority, which strength communicated in personal combats, institutions for the developement of the muscular system have been abandoned, until of comparatively late years. They afford us striking examples of the value of muscular exertion, not only in giving energy and pliancy to the frame, but as a means of preserving health.

The mean effect of the labour of an active man, working to the greatest possible advantage, and without impediment, is generally estimated to be sufficient to raise ten pounds, ten feet in a second, for ten hours in a day; or to raise one hundred pounds, which is the weight of twelve wine gallons of water, one foot in a second, or thirty-six thousand feet in a day; or three millions, six hundred thousand pounds, or four hundred and thirty-two thousand gallons, one foot in a day. Dr. Desaguliers affirms, that the weakest men, who are in health, and not too fat, lift about one hundred and twenty-five pounds: and the strongest of ordinary men four hundred pounds. Topham lifted eight hundred.

The daily work of a horse is estimated to be equal to that of five or six men.

In the *duration* of muscular contraction, we notice considerable difference between that of the voluntary and of the involuntary

* The approximate value of a *kilogramme* is about two pounds avoirdupois:—of a *myriagramme* about twenty.

muscles; the latter being much more rapid and alternating. The same remark applies to the voluntary muscles, when excited by some other stimulus than that of the will.

Contraction, excited by volition, can be maintained for a considerable time: of this we have examples in bearing a burden, the act of standing, holding the arm extended from the body, &c. In all these cases, the contractility of the muscles is sooner or later exhausted, fatigue is experienced, and it becomes necessary to give them rest; the power of contractility, however, is soon resumed, and they can be again put in action. This law of intermission in muscular action appears absolute;—relaxation being followed by contraction, in every organ, from the commencement of life until its final cessation. The intermission has, indeed, by many physiologists, been held to prevail—to a slight extent only, it is true—during, what we are in the habit of considering, continuous, muscular contraction. In proof of this, they cite the fact, that when we put the tip of the finger into the meatus auditorius externus, we hear a kind of buzzing or humming, which does not occur when an inert body is introduced. There are, however, other actions going on in the finger, besides this of muscular contraction; and it might, with as much propriety, be referred to the noise made by the progression of fluids in the vessels, as to the oscillations of muscular contraction and relaxation. We know not, in truth, whence the sound immediately proceeds.

In the *velocity* of muscular contraction, much difference also exists, according to the stimulus which sets it in action. If we apply galvanism to a muscle, we find the contractions at first exceedingly rapid; but they become progressively feebler, and require a stronger stimulus, until their irritability appears to be exhausted. Irritating the nerve, in these cases, is found to produce a greater effect, than when the stimulus is applied directly to the muscle. The velocity of voluntary contraction is, of course, variable, being regulated entirely by the will. We have, in various classes of the animal kingdom, remarkable instances of this velocity. The motions of the racer, of the grayhound, of a practised runner, of the fingers in playing upon musical instruments—as the violin, flute, piano-forte—and in writing, of the voice in enunciation, and of the upper and lower limbs in striking, leaping, and kicking, convey a general notion of this rapidity of contraction, and how nicely, in many cases, it must be regulated by volition. The fleetest race horse, on record, was capable of going, for a short distance, at the rate of a mile per minute; yet this is trifling, when compared with the velocity of certain birds—which can, with facility, wheel round and round the most rapid racer in circles of immense diameters—and with that of numerous small insects, which accompany us, when we travel with great rapidity—even against the wind—with apparent facility.

It has frequently excited surprise, how the migratory birds can support themselves so long upon the wing, as to reach the country of their migration, and, at the same time, live without food during their aerial voyage. The difficulties of the subject have impelled many to deny the fact of their migration; and, have excited others to form extravagant theories to account for the preservation of the birds during the winter months; but if we attend to their excessive velocity, the difficulties, in a great measure, vanish. Montagu, a celebrated ornithologist, estimates the rapidity with which a hawk and many other birds occasionally fly, to be not less than one hundred and fifty miles an hour; and that one hundred miles per hour is certainly not beyond a fair computation for the continuance of their migration. Major Cartwright, on the coast of Labrador, found by repeated observations, that the flight of the eider duck is at the rate of ninety miles an hour, yet it has not been esteemed very remarkable for its swiftness. Sir George Cayley computes the rate of flight, even of the common crow, at nearly twenty-five miles an hour. Spallanzani found that of the swallow about ninety-two miles an hour; and he conjectures, that the velocity of the swift is nearly three times greater. A falcon, belonging to Henry IV. of France, escaped from Fontainbleau, and was, in twenty-four hours afterwards, at Malta—a distance computed to be not less than one thousand three hundred and fifty miles, making a velocity of nearly fifty-seven miles an hour, supposing the falcon to have been on the wing the whole time; but, as such birds never fly by night, if we allow the day to have been at the longest, his flight was perhaps at the rate of seventy-five miles per hour. It is not probable, however, as Montagu observes, that it either had so many hours of light in the twenty-four hours to perform its journey, or that it was retaken at the moment of its arrival. Again, a society of pigeon fanciers from Antwerp, dispatched ninety pigeons from Paris, the first of which returned in four hours and a half, at a rate of nearly fifty miles an hour; and, in a number of the *New Monthly Magazine*, for 1826, there is an instance of the migratory or passenger pigeon—the *Columba migratoria* of Wilson—having been shot in Fifeshire, in Scotland. It was the first ever seen in Great Britain, and had been forced over, it was imagined, by unusually strong westerly gales.

The velocity of the contraction of the muscles of the wings, in these rapid flights is incalculable. The possible velocity, in any case, must be greatly dependant upon habit. Nothing can be more awkward than the first attempts at writing, drawing, playing on musical instruments, or performing any mechanical process in the arts; and what a contrast is afforded by the astonishing celerity, which practice never fails to confer, in any one of those varieties of muscular contraction? In running, leaping, wrestling, dancing, or any other motion of the body, one person can execute with facility, what another, with equally favourable original powers, cannot effect, because he has not previously and frequently made the attempt. Prize-fighting affords an instance of this kind of muscular velocity and precision, acquired by habit;—the practised boxer being able to inflict his blow and return his arm to the guard so quickly, as almost to elude the sight. By considering the muscular motions, employed in transporting the body of the fleetest horse, Haller has concluded, that the elevation of the leg must have been performed in $\frac{1}{70}$th part of a second. He calculates that the *rectus femoris*—the large muscle which is attached to the knee-pan and extends the leg—is shortened three inches in the $\frac{1}{28}$ th part of a second in the most rapid movements of man. But, he adds, the quickest motions are executed by the muscles, concerned in the articulation of the voice. He himself, in one experiment, pronounced fifteen hundred letters in a minute; and, as the relaxation of a muscle occupies as much time as its contraction, the contraction of a muscle, in pronouncing one of these letters, must have been executed in $\frac{1}{3000}$th part of a minute; and in much less time in some letters, which require repeated contractions of the same muscle or muscles, as *r*. If the tremors, that occur in the pronunciation of this letter, be estimated at ten, the muscles, concerned in it, must have contracted, in Haller's experiment, in $\frac{1}{30000}$th part a minute.

It has been the opinion of many physiologists and metaphysicians, that, only within certain limits of velocity, is muscular contraction directed by volition; and that when it exceeds a certain velocity, it evidently depends upon habit. The effects of volition have, in this respect, been divided into the *immediate* and *remote*. Of the first we have examples in the formation of certain vocal and articulate sounds, and in certain motions of the joints, as in the production of voice, speech, and locomotion. In the second, are included those actions, which we conceive to be within our power, but where we think only of the end to be obtained, without attending to the mechanical means. "In learning a language, for example," says Dr. Bostock, "we begin by imitating the pronunciation of the words, and use a direct effort to put the organs of speech in the proper form. By degrees however, we become familiar with this part of the operation, and think only of the words, that are to be employed, or even the meaning, that is to be conveyed by them. In learning music, we begin by imitating particular motions of the fingers, but at length the fingers are disregarded, and we only consider what sounds will follow from certain notes, without thinking of the mechanical way in which the notes are produced."

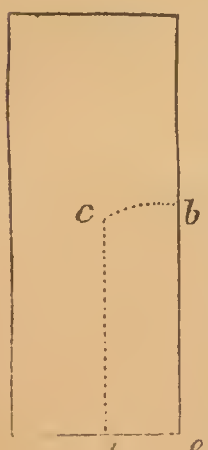
In these, however, and in all other cases that can be brought forward, it is difficult to conceive how the effect can be produced without the agency of volition;—obscure it is true, but still in action. The case of reading is often assumed, as confirming the view that invokes habit: yet, if a letter be inverted, we immediately detect it; and although, by habit, we may have acquired extreme facility in playing the notes of a rapid musical movement, no doubt, we think, ought to exist, that an effort of volition is exerted on each note composing it,—inasmuch as there is no natural sequence of sounds, and hence there appears no cogent reason, why one should follow rather than another, unless a controlling effort of the will were exerted.

With regard to the *extent* of muscular contractions, this must of course be partly regulated by volition; but it is also greatly owing to the length of the muscular fibres. The greater the length, of course the greater the decurtation during contraction. We shall see, likewise, that this depends upon the kind of lever, which the bone forms, and the distance at which the muscle is inserted from the joint or fulcrum.

Before passing to the examination of special movements, it will be necessary to consider briefly a few elementary principles of mechanics, most of which are materially concerned in every explanation, and without some knowledge of which such explanations would, of course, be obscure or unintelligible. Were we, as Magendie has remarked, to investigate narrowly every motion of the body, we should find the applicability to them of almost all the laws of mechanics.

If we take a rod of wood or metal, of uniform matter throughout, and support it at the middle, either like the beam of a balance, or on a pointed body, we find, that the two ends accurately balance each other; and if we add weights at corresponding parts of each arm of the beam, that is, at parts equidistant from the point of suspension, the balance will still be maintained. The point, by which the beam is suspended, or at which it is equilibrious, is called the *centre of gravity* of the beam; and, in every mass of matter, there is a point of this kind, about which all the parts balance or are equilibrious; or, in other words, they have all this centre of gravity or of inertia.

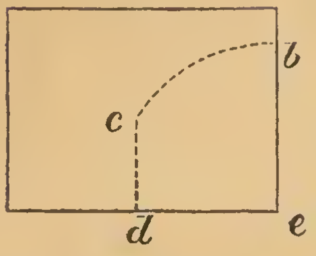
Fig. 62.



The centre of gravity, in a mass of regular form and uniform substance, as in the parallelograms, Figs. 62 and 63, is easily determined, inasmuch as it must necessarily occupy the centre *c*; but in bodies, that are irregular, either as regards density or form, it has to be determined by rules of calculation, to be found in all works on physics, but which it is unnecessary to adduce here.

The nearer the centre of gravity is to the soil on which the body rests, the more stable is the equilibrium. In order that the figures 62 and 63 shall be overturned from left to right, the whole mass must turn upon *e* as upon a pivot; the centre of gravity describing the curve *c b*, and the whole mass being lifted in the same degree. In Fig. 62, the curve is nearly horizontal, owing to the narrowness of the base and the height of the centre of gravity. In Fig. 63, on the other hand, whose base is broad and the centre of gravity low, the curve rises considerably; the resistance to overturning is consequently nearly equal to the whole weight of the body, and the equilibrium necessarily firm.

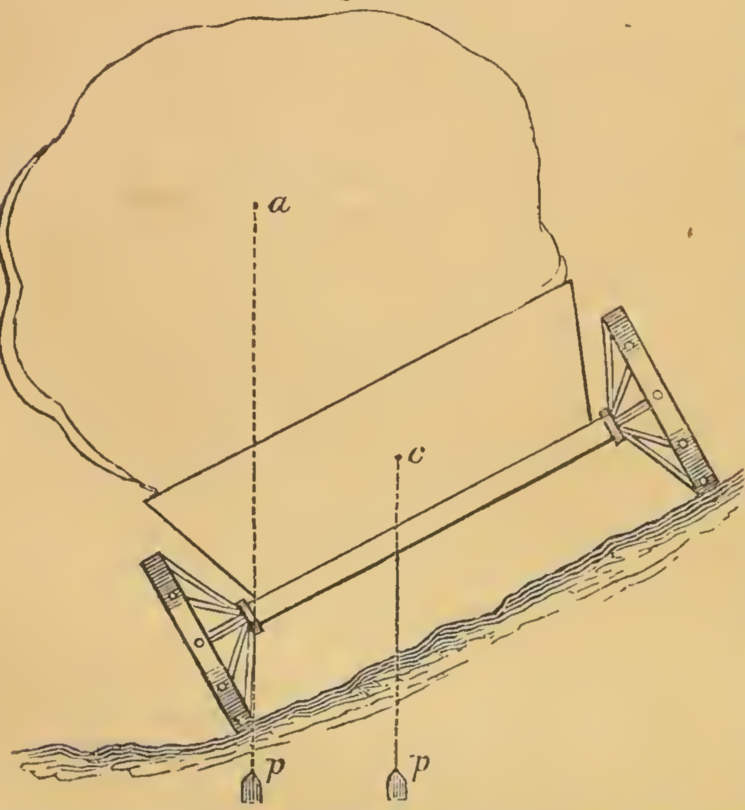
Fig. 63.



The condition of equilibrium, of a body resting upon a plane, is such, that a perpendicular, let fall from the centre of gravity, shall fall within the points by which it touches the plane. This perpendicular is called the *vertical line* or *line of direction*, being that in which it tends naturally to descend to the earth; and the space, comprised between the points by which the body touches the soil, is called the *base of sustentation.*

We can now understand, why a wagon, loaded with heavy goods, may pass with safety along a sloping road; whilst, if it be loaded to a greater height with a lighter substance, it may be readily overturned. When the wagon is loaded with metal, the centre of gravity is low as at *c*; the vertical line *c p* falls considerably within the base of sustentation; and the centre describes a rising path; but in the other case the centre is thrown higher, to *a*; and the vertical line falls very near the wheel, or on the outside of it, and consequently of the base, whilst the centre describes a falling path.

Fig. 64.



Of two hollow columns, formed of an equal quantity of the same matter and of the same height, that, which has the largest cavity, will be the stronger of the two; and of two columns of the same diameter, but of different heights, the higher will be the weaker.

All bodies tend to continue in the state of motion or of rest, so as to render force necessary to change their state. This property is called the *inertia of motion* or of *rest*, as the case may be.

When a carriage is about to be moved by horses, considerable effort is necessary to overcome the *inertia of rest;* but if it move with velocity, effort is also required to arrest it, or to overcome the *inertia of motion.*

We can thus understand, why, if a horse starts unexpectedly, it is apt to get rid of its burden; and why an unpractised rider is projected over his horse's head if it stop suddenly. In the former case, the inertia of rest is the cause of his being thrown; in the latter, the inertia of motion. The danger of attempting to leap from a carriage, when the horses have taken fright, is thus, likewise, rendered apparent. The traveller has acquired the same velocity as the vehicle; and if he leap from it, he is thrown to the ground with that velocity; thus incurring an almost certain injury to avoid one more remotely contingent.

The *force, momentum,* or *quantity of motion* in a body is measured by the velocity, multiplied into the quantity of matter. A cannon ball, for example, may be rolled so gently against a man's leg, as not even to bruise it; but if it be projected by means of gunpowder, it may mow down a dense column of men, or penetrate the most solid substances. If a man be running, and strike against another, who is standing, a certain shock is received by both; but if both be running in opposite directions with the same velocity, the shock will be doubled.

The subject of the direction of forces applies to most cases of muscular movements. Where only one force acts upon a body, the body proceeds in the direction in which the force is exerted; as in the case of a bullet fired from a gun; but if two or more forces act upon it at the same time, the direction of its motion will be a middle course between the directions of the separate forces. This course is called the *resulting direction,* that is, *resulting* from the *composition of the forces.* Let us suppose two forces *a* T and *b* T in Fig. 65, acting upon the body T, which may be regarded as the tendon of a muscle, and the two forces as the power developed by muscular fibres holding the same situation; the result will be the same, whether they act together or in succession. For example, if the force *a* T is sufficient to draw T to *a*, and immediately afterwards the force *b* T be exerted upon it, the tendon will be at *c*, the place to which it would be drawn by the simultaneous action of the two forces or fibres. If, therefore, we complete the figure, by drawing *a c* equal and parallel to T *b*, and *c b* equal and parallel to *a* T, we have the *parallelogram of forces,* as it is called, of which the diagonal shows the *resultant* of the forces, and the course of the body on which they abt.

Fig. 65.

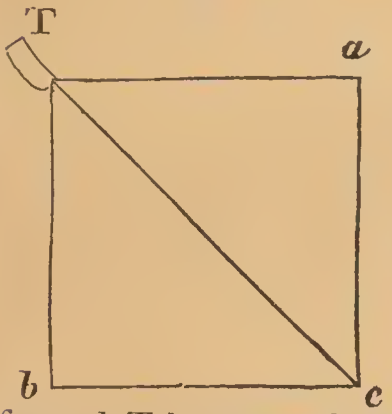
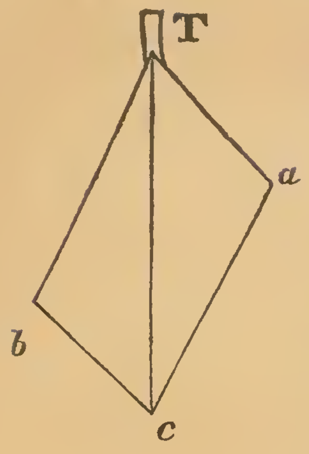


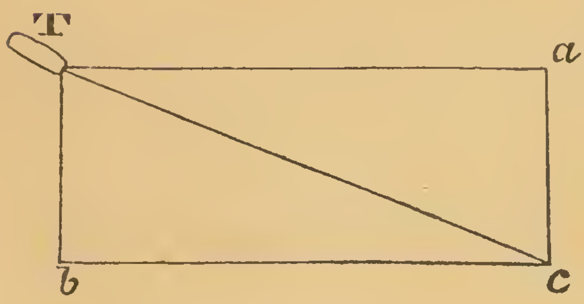
Fig. 66.



In the case, assumed in Fig. 65, the forces are equal. If not so, the parallelogram may result as in Fig. 67; in which T *c* will, again, be the resultant of the forces *a* T and T *b*, or we may have the arrangement in Fig 66.

By these parallelograms, we are enabled, also, to resolve the resultant into its component forces. Suppose, for example, we are desirous of knowing the quantity of force in the resultant T *c*, Fig. 65, which is capable of acting in the directions T *a* and T *b*; it is only necessary to draw, from the point *c*, *c a* parallel to T *b*, and *c b* parallel to T *a;* and the lines T *a* and T *b*, cut off by these, will be the forces into which it may be resolved. The same applies to Figs. 66 and 67, and to every other of the kind.

Fig. 67.



Friction is the resistance necessary to be overcome in making one body slide over another; and *adhesion* is the force, which unites two polished bodies when applied to each other,—a force, which is measured by the perpendicular effort necessary for separating the two bodies. The more polished the surfaces in contact, the greater is the adhesion, and the less the friction; so that where the object is merely to facilitate the sliding of one surface over another, it will be always advantageous to make the surfaces polished, or to put a liquid between them.

A beam or rod of any kind, resting at one part on a prop or support, which thus becomes its centre of motion, is a *lever*. The ten inch beam, P. W, Fig. 68, is a lever, of which F may be considered the *prop* or *fulcrum;* P, the part at which the *power* is applied, and W, the point of application of the *weight* or *resistance*. In every lever we distinguish three points;—the *fulcrum*, *power*, and *resistance;* and, according to the relative position of these points, the lever is said to be of the *first*, *second*, or *third kind*.

Fig. 68.

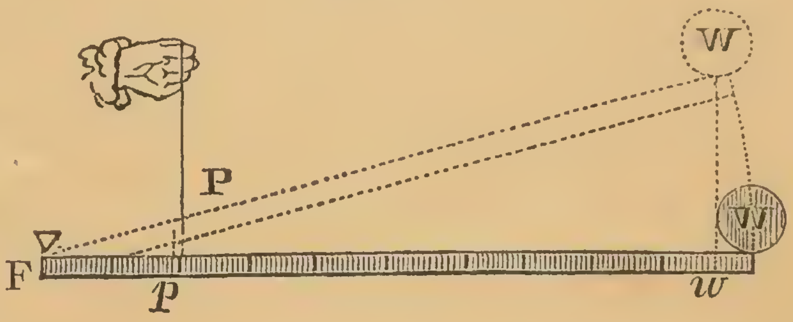
In a lever of the first kind, the fulcrum is between the resistance and the power as in Fig. 68; F being the fulcrum on which the beam rests and turns; P, the power; and W, the weight or resistance. We have numerous familiar examples of this lever;—the crow-bar in elevating a weight;—the handle of a pump;—a pair of scales;—steelyard, &c.

A *lever of the second kind* has the resistance W, Fig. 69, between the power P and the fulcrum F; the fulcrum and power occupying each one extremity. The rudder of a ship, a wheel-barrow, and nut-crackers, are varieties of this kind of lever.

Fig. 69.

In a *lever of the third kind*, the power P is between the resistance W, and the fulcrum F, Fig. 70; the resistance and the fulcrum occupying each one extremity of the lever. In the two last levers, the weight and the power change places. Tongs and shears are levers of this kind; and also a long ladder raised against a wall by the efforts of a man: here, the fulcrum is at the part of the ladder, which rests on the ground; the power is exerted by the man; and the resistance is the ladder above him.

Fig 70.



In all levers are distinguished,—the *arm of the power*, and the *arm of the resistance*. The former is the distance comprised between the power and the fulcrum, P F, Figs. 68, 69, and 70; and the latter is the distance W F, or that between the weight and the fulcrum. When, in the lever of the first kind, the fulcrum occupies the middle, the lever is said to have equal arms; but if it be nearer the power or the resistance it is said to be a lever with unequal arms.

The length of the arm of the lever gives more or less advantage to the power or to the resistance, as the case may be. In a lever of the first kind, with equal arms, complete equilibrium would exist, provided the beam were alike in every other respect. But if the arm of the power be longer than that of the resistance, the resistance is to the power as the length of the arm of the power is to that of the arm of the resistance; so that if the former be double or triple the latter, the power need only be one-half or one-third of the resistance, in order that the two forces be in equilibrium. A reference to the figures will exhibit this in a clear light. The three levers are all presumed to be of equal substance throughout, and to be ten inches, or ten feet in length.

The arm of the power, in Fig. 68, is the distance P F, equal to eight of those divisions: whilst that of the resistance is W F, equal to two of them. The advantage of the former over the latter is, consequently, in the proportion of eight to two, or as four to one; in other words, the power need only be one-fourth of the resistance, in order that the two forces may be equilibrious.

In the lever of the second kind, again, the proportion of the arm P F of the power, is to that, W F, of the resistance, as ten—the whole length of the lever—to two; or as five to one: whilst, in the lever of the third kind, it is as two to ten, or as one to five; in other words,—to be equilibrious, the power must be five times greater than the resistance.

We see, therefore, that, in the lever of the second kind, the arm of the power must necessarily be longer than that of the resistance, since the power and the fulcrum are separated from each other by the whole length of the lever: hence, this kind of lever must always be advantageous to the power; whilst the lever of the third kind, for like reasons, must always be unfavourable to the power, seeing that the arm of the resistance is the whole length of the lever, and, therefore, necessarily greater than that of the power.

It can now be understood, why a lever of the first kind should be the most favourable for equilibrium; one of the second kind for overcoming resistance; and one of the third kind for rapidity and extent of motion: for whilst, in Fig. 70, the power is moving through the minute ark at P, in order that the lever may assume the position indicated by the dotted lines F w, the weight or resistance is moving through the much more considerable space W *w*.

The direction in which the power is inserted in to the lever, likewise demands notice. When it is perpendicular to the lever, it acts with the greatest advantage; the whole of the force developed being employed in surmounting the resistance; whilst, if inserted obliquely, a part of the force is employed in tending to move the lever in its own direction; and this part of the force is destroyed by the resistance of the fulcrum.

Lastly, the general principle of equilibrium in levers consists in this;—that whatever may be the direction in which the power and resistance are acting, they must always be to one another inversely as the perpendiculars drawn from the fulcrum to their lines of direction. In Fig. 70, for example, the line of direction of the upper weight is W *w*; that of the power P *p*; and to keep the lever in equilibrium in this position, the forces must be to one another inversely as F *w* to F *p*.

In applying these mechanical principles to the illustration of muscular motion, we must, in the first place, regard each movable bone as a lever, whose fulcrum or centre of motion is in its joint; the power at the insertion of the muscle; and the resistance in its own weight and in that of the parts which it supports.

In different parts of the skeleton we find the three kinds of levers. Each of the vertebræ of the back forms, with the one immediately beneath it, a lever of the first kind; the fulcrum being seated in the middle of the under surface of the body of the vertebra. The foot, when we stand upon the toe, is a lever of the second kind; the fulcrum being in the part of the toes resting upon the soil, the power in the muscles inserted into the heel, and the resistance in the ankle joint, on which the whole weight of the body rests. Of levers of the third kind we have numerous instances; of which the deltoid, to be described presently, is one. In this, as in other cases, we shall see the applicability of the principle, laid down regarding the arms of the lever, &c., and we shall find, that, in the generality of cases, the power is inserted into the lever so near to the fulcrum, that considerable force must be exerted to raise an inconsiderable weight;—that so far, consequently, mechanical disadvantage is occasioned; but we shall find, that such disadvantages enter into the economy of nature, and that they are attended with so many valuable concomitants, as to compensate richly for the expense of power. Some of these causes, that tend to diminish the effect of the forces, we will first consider, and afterwards attempt to show the advantages resulting from these and similar arrangements in effecting the wonderful, the complicate operations of the muscular system.

In elucidation of this subject let us take, with Haller, the case of the deltoid—the large muscle, which constitutes the fleshy mass on the top of the arm, and whose office it is to raise the whole of the upper extremity.—Let W F, Fig. 71, represent the os humeri, with a weight W at the elbow, to be raised by the deltoid muscle D. The fulcrum F is necessarily, in this case, in the shoulder joint; and the muscle D is inserted much nearer to the fulcrum than to the end of the bone on which the weight rests; the arm of the power *P* F, (supposing, for a moment, that it is acting at this part with every advantage, which we will see presently, it is not,) is, consequently, much shorter than that of the resistance W F, which, as in all levers of the third kind, occupies the whole length of the lever. In estimating the effect from this cause alone upon the power to be exerted by the deltoid; we will suppose, that the arm of the power is to that of the resistance as 1 to 3; the deltoid being inserted into the humerus about one-third down. Now, if we raise a weight of fifty-five pounds in this way, and add five pounds for the weight of the limb, (which may be conceived to act entirely at the end of the bone,) the power, which the deltoid must exert, to produce the effect, is not equal to sixty pounds, but to three times sixty, or one hundred and eighty pounds.

Fig. 71.

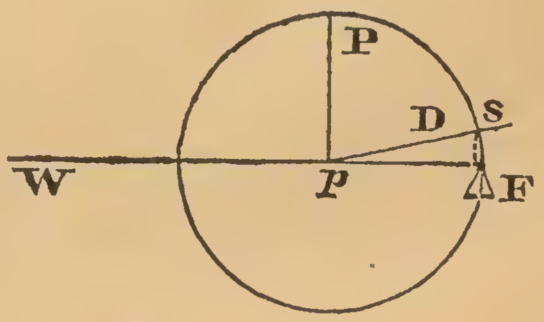
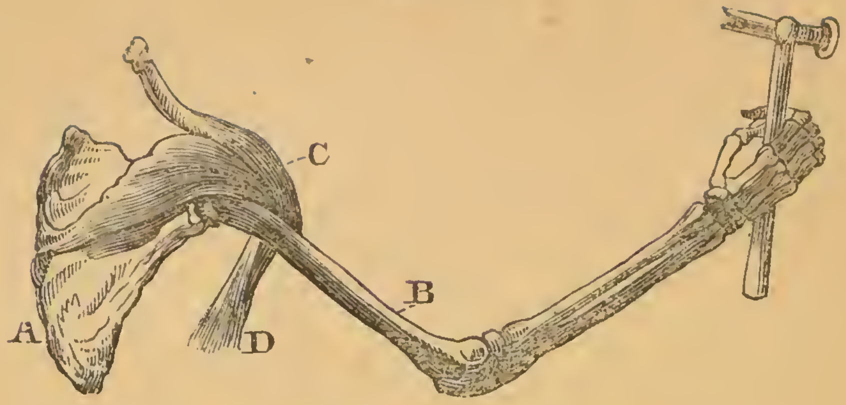


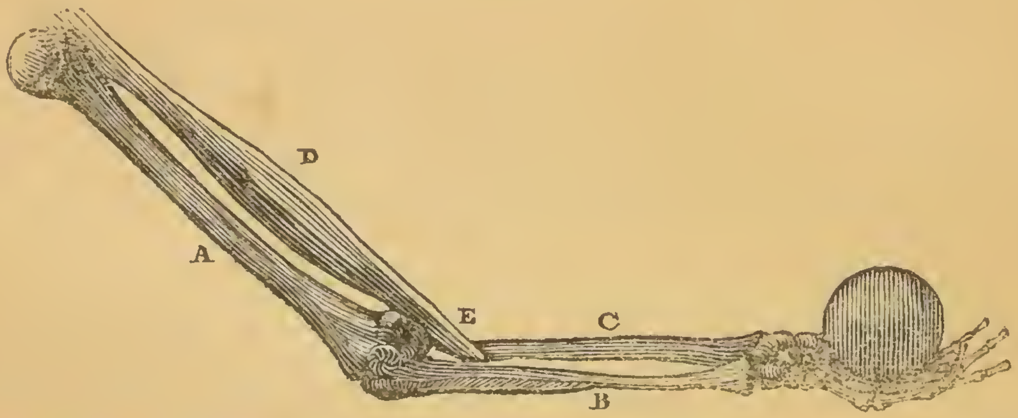
Fig. 72.



A. the Scapula, B. the os humeri, C. the deltoid.

Figure 72, strikingly exhibits the disadvantages of the deltoid, so far as regards the place of its insertion into the lever; but many muscles have insertions much less favourable than the deltoid. The biceps, D, for example, in Fig. 73,—the muscle which bends the forearm on the arm,—is attached to the forearm ten times nearer the elbow-joint, or the fulcrum, than to the extremity of the lever; and if we apply the argument to it,—supposing the weight of the globe, in the palm of the hand, to be fifty-five pounds and the weight of the limb five pounds—it would have to act with a force equal to sixty times ten, or six hundred pounds to raise the weight.

Fig. 73.



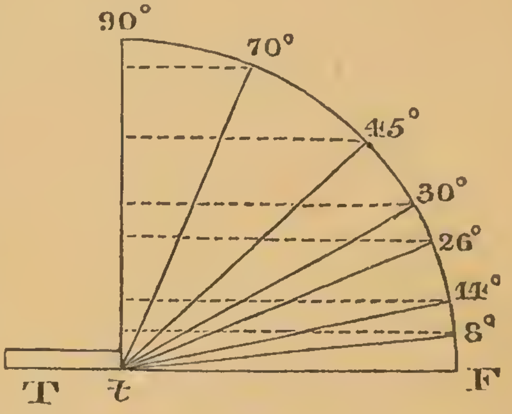
A, the os humeri; B, the ulna; C, the radius; D, the biceps; E, insertion of the biceps into the radius.

Muscles, again, are attached to the bones at unfavourable angles. If they were inserted at right angles, in the direction P *P*, Fig. 71, the whole power would be effectually applied in moving the limb. On the other hand, if the muscle were parallel to the bone, the resistance, it is obvious, would be infinite, and no effect could result.

In the animal, it rarely happens, that the muscle is inserted at the most favourable angle: it is generally much smaller than a right angle. Reverting to the deltoid, this muscle is inserted into the humerus at an angle of about ten degrees. Now, a power, acting obliquely upon a lever, is to one acting perpendicularly, as the sine of inclination, represented by the dotted line F s, Fig. 70, to the whole sine, P *P*. In the case of the deltoid the proportion is as 1,736,482 to 10,000,000. Wherefore, if the muscle had to contract with a force of one hundred and eighty pounds, owing to the disadvantage of its insertion near the fulcrum, it will have, from the two causes combined, to exert a force equal to 1,058 pounds.

Again, the direction, in which the fibres are inserted into the tendon, has great influence on the power developed by the muscles. There are but few straight muscles, in which the fibres have the same direction as the tendon. Fig. 74 will exhibit the loss of power, which the fibres must sustain in proportion to the angle of insertion. The fibre T *t* F would, of course, exert its whole force upon the tendon, whilst the fibre *t* 90° would, by its contraction, merely displace the tendon. Now, the force exerted

Fig. 74.



is, in such a case, to the effective force,—that is, to that which acts in moving the limb,—as the whole sine *t* F is to the sines of the angles at which the fibres join the tendon, represented by the dotted lines. Borelli and Sturm have calculated these proportions as follows:—At an angle of 30°, they are as 100 to 87; at 45° as 100 to 70; at 26° as 100 to 89; at 14° as 100 to 97, and at 8° as 100 to 99.

The largest angle, formed by the outer fibres of the deltoid, is estimated by Haller at 30°; the smallest about 8°. If this disadvantage be taken into account, the deltoid will have to contract, with a force equal to 1,284 pounds, to raise fifty-five pounds at the elbow.

It is farther contended by Borelli, Sturm, and Haller, that the force of the muscle, as estimated in the preceding calculations, must be doubled, seeing that it has to exert as much force in resisting the bone which affords a fixed point at one extremity, as in elevating the weight at the other. This estimate, if admitted, would elevate the force, which must be exerted by the deltoid in raising the fifty pounds, to 2,568 pounds.

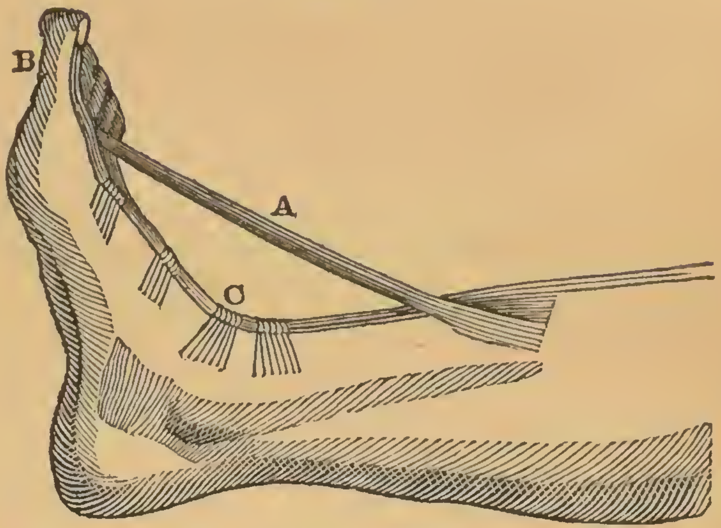
Lastly; much force is spent when a muscle passes over many joints. Antagonist muscles must, likewise, exert an influence of this kind, consuming a certain portion of the force developed in the contraction of the muscle.

On the other hand, there are certain arrangements, which augment the power developed by muscles; as the thick articular extremities of the bones; the patella and the sesamoid bones in general; all of which enlarge the angle, at which the tendon is inserted into the bone or lever. The projecting processes for muscular attachments, as the trochanters, the protuberance of the os calcis, the spinous processes of the vertebræ, &c. augment the arm of the lever and are thus inservient to a like valuable purpose. The smoothness of the articular surfaces of bones,—tipped, as they are, with cartilage, and the synovia, which lubricates the joints, by diminishing the friction, also augment the power, as well as the bursæ mucosæ, which are interposed wherever there is much pressure or friction. The trochleæ or pulleys act only in directing the force, without augmenting its amount; and the same may be said of the bony canals and tendinous sheaths, by which the tendons of the muscles, especially those passing to the fingers and toes, are kept in their proper course.

Still, it must be admitted, that, as regards the effort to be exerted by the muscles, it must, in almost all cases, be much greater than the resistance it has to overcome. The very fact of the lever of the third kind being that which prevails in our movements exhibits this. The mere mechanician has conceived this to be an unwise construction; and that there is a needless expense of force for the attainment of a determinate end. In all cases we find, that the expense of power has been but little regarded in the construction of the frame; nor is it necessary that it should have been. It must be recollected, that the contraction of the muscle is under the influence of volition, and that, within certain limits, the force, to be employed, is regulated by the influx sent by it into the muscles. The great object, in the formation of the body, appears to have been;—to unite symmetry and convenience, with the attainment of great velocity and extent of motion, so that, whilst the power is moving through but a small space, the weight or resistance shall move rapidly through one more extensive. We have seen that, in these respects, the lever of the third kind is most fitting. With any other, indeed, less power might be required; but we should have less extent of motion and less velocity, whilst the symmetry and convenience of the body would be destroyed. Suppose, for example, that in Fig. 73, the biceps—instead of being inserted at E, near the elbow—had passed on to the wrist, or, to simplify the matter, to the extremity of the member; it would assuredly have acted with more force—the lever having been changed into one of the second kind—but the hand would have lost that velocity and extent of motion, which are so important to it; and the course of the muscle would have been so modified, as to convert the convenient and symmetrical member into a cumbrous, webbed instrument, badly adapted for the multitudinous purposes to which it has to be applied.

The same effect results, as Sir Charles Bell has remarked, from the course of the tendons and their confinement by sheaths, strengthened by ligament.

Fig. 75.



If the tendon A, Fig. 75, took the shortest course to its termination at B, it would draw up the toe with more force; but the toe would lose its velocity of movement.

To favour this velocity, we find, that the majority of muscles are inserted obliquely into their levers, and the fibres into the tendons. By this arrangement, as we have proved, considerable loss of power results; but, in the majority of cases, the motion is effected by a less degree of decurtation than if the muscle were straight.

Let A B and C D, Figs. 76 and 77, be parts of two ribs, that are parallel, and will continue parallel till they are brought in contact by the action of the straight muscle E F; or by that of the oblique muscles F G and F H. Now, it is obvious, that, when the point E comes in contact with F, the length of the straight muscle E F must be null; whilst that of the oblique muscles will only have experienced a decurtation equal to G *g* and H *h*, Fig, 76; and to F *g* and

Fig. 76.

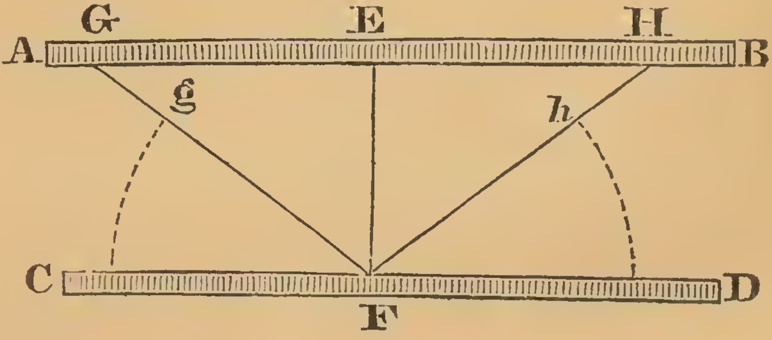
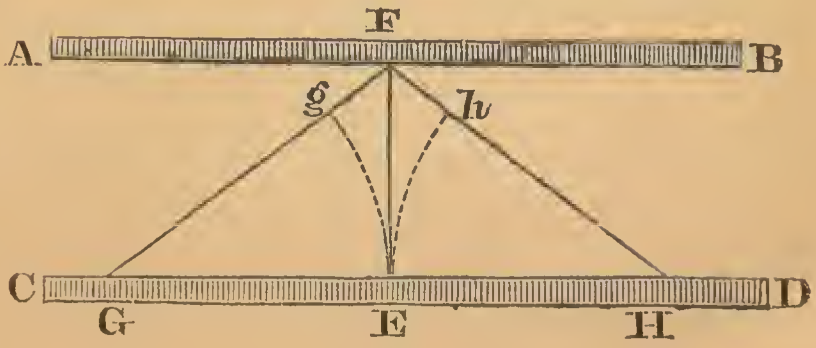
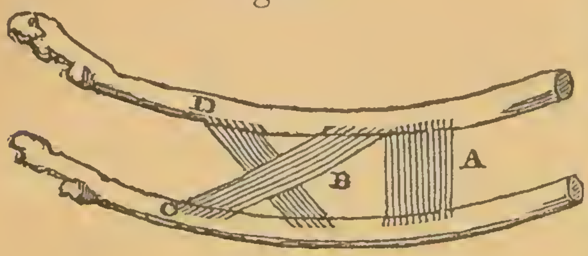


Fig. 77.



F *h*, Fig. 77. It is clear, also, that, in these cases, the straight muscles can never so contract as to admit of a close approximation of the ribs; whilst the oblique muscles will admit of this to a much greater extent. We can, therefore, understand, why the intercostal muscles pass obliquely from one rib to another, as at D and B C, Fig. 78, instead of in a direction perpendicular to the two ribs, as at A.

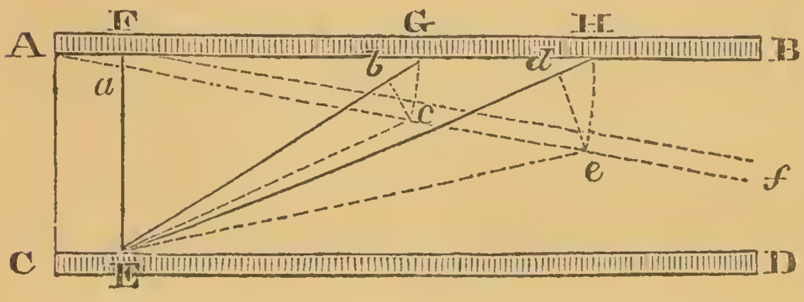
Fig. 78.



There are cases, however, in which a straight muscle may pass between two parallel ribs, and carry them through a given space, with less decurtation of fibres, than any oblique muscle, which has the same origin, but is inserted at a greater distance from the centre of motion, and acts through the medium of a longer lever. Moreover, a muscle, with a less degree of obliquity, may be so situated as to carry the bones through a given space with a less decurtation of fibres than any other muscle having the same origin, but a much greater degree of obliquity.

Suppose A B and C D, Fig. 79, to be two parallel ribs, of which A B is movable about A, as a centre; and suppose it to be brought, by the action of the straight muscle E F, and of the oblique muscles E G and E H, into the position A *f*. The points of insertion of the muscles will now be at *a*, *c*, and *e*, after having traversed the spaces F *a*, G *c*, and H *e*. If we, now, from the point E, as a centre, describe the arcs *c b* and *e d;* the spaces *d* H and *b* G will indicate the degree of decurtation, which the oblique muscles have experienced, and *a* F that of the straight muscle.

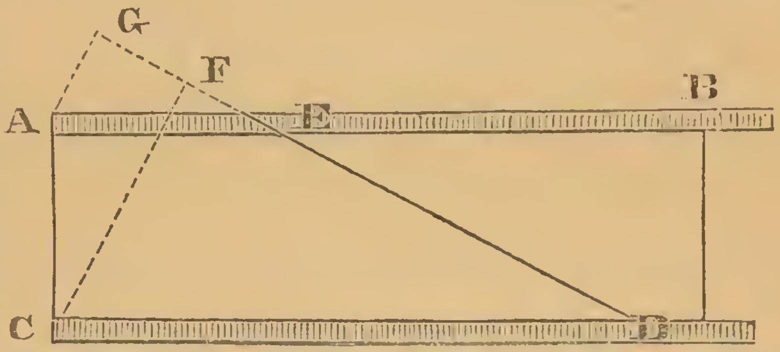
Fig. 79.



This figure also shows, that when the muscles change the relative position of any two bones, they, at the same time, change the direction of their own action, and vary their lever. When the rib A B is brought into the position A *f*, the muscles E G and E H, by being brought down to *c* and *e*, have assumed the positions E *c* and E *e*, and have, consequently, changed their length, situation, obliquity, and leverage.

Again, of the muscles, that are attached to ribs that are parallel, equally movable, and situated at right angles to the spine, those which pass perpendicularly from one rib to the other, will act upon each with equal leverage, and each will approach the other with the same velocity; whilst those, which pass obliquely from one to the other, will make them approach with different velocities; a principle which is strikingly applicable to the intercostal muscles. Let us suppose A B and C D, Fig. 80, to be two parallel ribs, articulated with the spine at A and C, and that they are equally movable on these centres of motion. Let D B represent a straight muscle, passing directly from the one rib to the other; and D E an oblique muscle. The levers of D B, according to the mechanical principle laid down, will be A B and C D, perpendiculars drawn from the centres of motion to the line of direction of the power. These levers, being parallel, are of course equal, but the levers of D E will be C F and A G, perpendiculars drawn from the centres of motion to the line of direction of the power. These levers are of different lengths, and, accordingly, the muscle must act with different degrees of force on the two ribs; so that it will cause C D, on which it acts with the longest lever, to approach A B faster than it makes the latter approach the former,—in the ratio of C F to A C, or with three times the velocity.

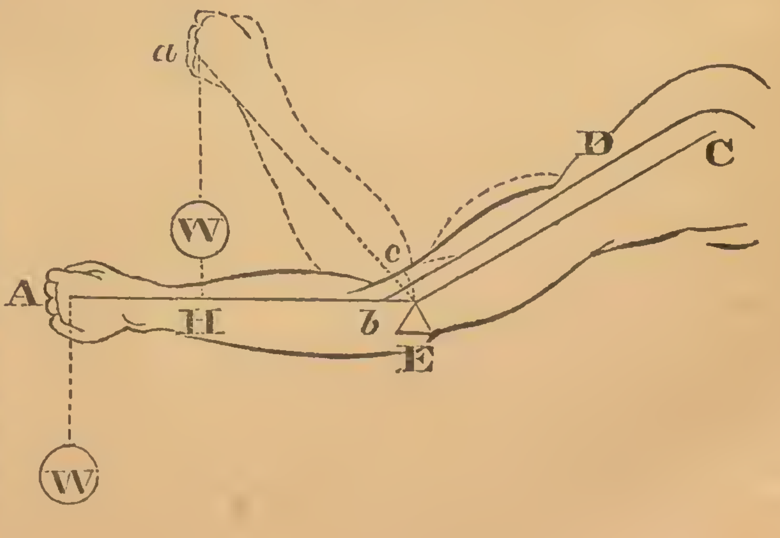
Fig. 80.



In all muscular motions, the levers of the power and of the resistance are undergoing variation; so that the degree of power, necessary to be developed in one position of the member, may be much less than in another. The case of the biceps, already referred to, will elucidate this.

Let E C, Fig. 81, represent the os humeri; E A the forearm; E the elbow joint; W, a weight or resistance, hung at the wrist, and D the biceps muscle, inserted at *b*, a tenth of the distance down the forearm. It is manifest, that the force, necessary for bending the arm, must be much greater when it is in the position A E than in that of E *a*. The lever of the resistance, in the former case, is the whole length of

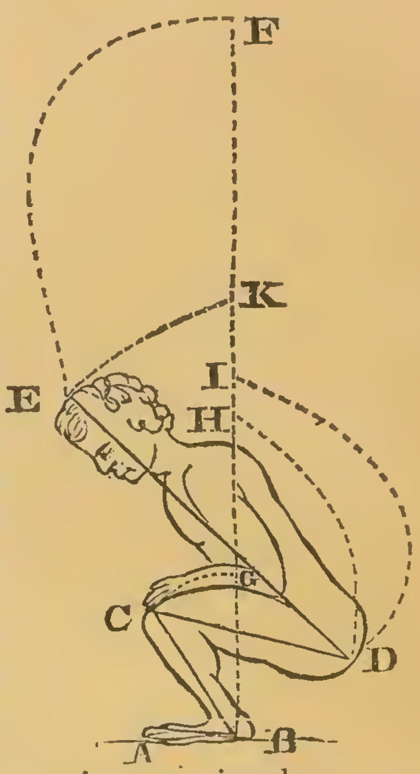
Fig. 81.



the forearm; or, in other words, the perpendicular drawn from the fulcrum to the line of direction of the weight W; but, when the arm is raised to *a*, the lever of the resistance is, no longer, E A; it is E H: but not only is the lever of the resistance shortened; that of the power is augmented. The lever of the biceps, when the forearm is horizontal, is the dotted perpendicular, drawn from the fulcrum at the elbow to the line of direction of the muscle; but when the forearm is bent to the position E *a*, the disposition of the muscle is also modified. It assumes the position, occupied by the dotted line, which is farther distant from the fulcrum, and the lever of the power is consequently increased. In this case, then, of the action of the biceps, in proportion as we raise the arm, the mechanical disadvantages become less and less; the lever of the power increasing, whilst that of the resistance diminishes.

In many of the changes of position of the body, whilst a bone is turning upon its centre of motion, the centre itself is often describing, at the same time, a curve. In Fig. 82, let A B represent the foot, B C the tibia, C D the thigh bone, and D E the trunk; and let us suppose it is required to bring the body to the erect position B F; so that B C shall correspond to B G, C D to G I, and D E to I F. The point C will describe the curve C G; and, whilst it is accomplishing this, the point D is likewise moving; so that the latter, instead of describing the curve D H, which it would do, were the centre of motion C fixed, proceeds along the curve D I; the point E, again, is subjected to the like influence, and instead of describing the curve E K, which it would do if the centre D were fixed, rises along E F.

Fig. 82.



The motions, produced by the muscles, may be either simple or compound. The simple muscles admit of variety; some being straight, composed of parallel fasciculi, others reflected in their course, and others, again, are circular.

In the straight muscles, each fibre, by its contraction, draws the tendon in its own direction; and the effect of the whole is to bring it towards the centre of the muscle. In a long muscle, the whole contractile effort is concentrated on the tendon, in consequence of the course of the fibres being parallel to that of the tendon. In most of the broad muscles, on the other hand, as the attachments at both extremities are usually at different points, all the fibres do not concur in one effort. Different sets of fibres may have a very different action from others, and they are capable of being thrown separately into contraction. The ordinary direction, in which a muscle acts, is from its tendinous back to its aponeurotic attachment—that is, from the movable to the more fixed part; and, in a straight muscle, this direction can be accurately appreciated. It must be borne in mind, however, that the muscle can act in an inverse direction also.

When the whole of the fibres, composing a broad muscle, are brought to act on the tendon, as in the case of the deltoid, we find, by the composition of forces, that the middle line of direction must be taken for the purpose of estimating their line of action. A part, however, may act and carry the arm upwards and outwards; whilst the opposite fibres may move it upwards and inwards.

Where a muscle is reflected,—like the superior oblique of the eye, and the peronei muscles,—the line of motion will be from the insertion to the point of reflection; precisely as a rope, passing over a pulley, raises the weight in a line drawn from the weight to the pulley.

The circular muscles, which have no precise origin or insertion, are inservient to the contraction of the apertures around which they are placed.

In executing the complex movements of any part of the frame, a combination of the action of the different muscles, attached to the part, generally occurs, rendering the process one of a complicated character. This, if no other cause existed, would render it extremely difficult to calculate the precise degree of force, which particular muscles, alone or in combination, are capable of exerting. The mathematical physiologists made multifarious attempts in this direction; but their conclusions were most discrepant. When we bear in mind, that the force, capable of being exerted by any muscle, is dependent upon the proper organization of the muscle, and likewise upon the degree of energy of the brain, it will be apparent, that all attempts of this kind must be futile. We can determine, with nicety, the effect of which the parts are capable, supposing them inanimate structures. We can calculate the disadvantages, caused by the insertion of the power near the fulcrum; by the obliquity of the line of action of the power, &c.; but we have not the slightest data for estimating the effect, produced by the nervous influx,—by that mysterious process, which generates a new force, and infuses it into the muscles, in a manner so unlike that in which the ordinary mechanical powers are exerted. The data, necessary for such a calculation, would be the precise influx from the brain,—the irritability of the muscle,—the mechanical influences, dependent on the straight or oblique direction of the fibres composing the muscle, as regards the tendon,—the perpendicular or oblique direction in which the tendon is attached to the bone,—the particular variety of lever,—the length of the arm of the power and of that of the resistance,—the loss sustained from friction, and the diminution of such loss caused by the cartilages that tip the bones, and by the synovia, &c.—data, which it is impossible to attain; and hence the solution of the problem is impracticable.

One great source of the combination of muscular motions is, the necessity for rendering one of the attachments fixed in order that the full force may be developed on the other. In but few of the muscles is the part, whence the muscle originates, steady. To these few, the muscles of the eye belong, which arise from the inner part of the orbit and pass forward to be inserted into the organ. To show how distant muscles may be concerned in this fixation of one end of a muscle, when it is excited to the developement of plenary power, we will take the case of the deltoid. This muscle arises from the scapula and clavicle, and is inserted into the os humeri; but the scapula and clavicle, themselves, are not entirely fixed; and, accordingly, if the deltoid were to contract alone, it would draw down the scapula and clavicle, as well as elevate the humerus. If, therefore, it be important to produce the latter effect only, the scapula and clavicle must be fixed by appropriate muscles; as by the rhomboidei, trapezius, &c. These muscles, however, arise from various vertebræ of the neck, which are themselves movable. It becomes necessary, therefore, that the neck should be fixed by its extensors, which arise from the lumbar and dorsal regions. By the united action of all these muscles, the deltoid is able to exert its full effect in elevating the humerus. But the deltoid, like other muscles, is capable of acting inversely; as in the case of a person lying on the ground, and attempting to raise himself, by laying hold of any object above him. The hand and forearm are thus rendered firm, and the deltoid now contracts from origin to insertion, and, consequently, elevates the scapula and clavicle.

Again, if a person, in the recumbent posture, endeavour to bend the head forwards, the recti muscles of the abdomen are firmly contracted, for the purpose of fixing the sternum, whence the sterno-cleido-mastoidei muscles in part arise, which can then exert their full power in bending the neck forwards.

These instances will be sufficient to exemplify the mode in which the muscular motions are combined. The same principle prevails over the whole body; and, where a greater number of parts has to be moved, the case must, necessarily, be still more complex.

When a part, movable in various directions, is contracting towards any point, it must be rendered steady, and be prevented from deviating, by the muscles on each side; and the extent of its motion may be partly regulated by the action of antagonist muscles. Supposing, for instance, that the head is inclined forwards, there must be muscles, not only to move it in that direction, but also to prevent it from inclining to the right or left, and to limit the motion forwards; although doubt may arise, whether this be not entirely effected by the nervous influx, sent by volition to the flexors of the head. Hence, some anatomists have considered, that there must, in these cases, be movers, directors, and moderators.

In sleep, the muscles are perhaps in the most complete state of relaxation; and, hence, this condition has been invoked, as affording evidence of the comparative preponderance of particular antagonizing muscles,—the flexors and extensors, for example. In perfect sleep, when no volition is exercised over the muscles, we find the body reposing in a state of semiflexion,—which seems to show, that the flexor muscles have slightly the advantage over the extensors. Richerand, in a memoir laid before the *Société de Médecine* of Paris, in 1799, assigned the following reasons for this preponderance. *First.* The number of flexors is greater than that of extensors. *Secondly.* The fibres, composing them, are more numerous and longer:—take, for examples, the sartorius, gracilis, semi-tendinosus, semi-membranosus, and biceps, which are the flexors of the leg, and the rectus and triceps cruris, which are its extensors. *Thirdly.* Their insertion is nearer the resistance and farther from the centre of motion, which adds to their force. *Fourthly.* Their insertion into the bones is at a larger angle, and nearer to the perpendicular; and *Fifthly.* Their arrangement is such, that the continuation of the movement of flexion renders them perpendicular to the bones to be moved.

The explanation, afforded by Richerand, applies, on the whole, to the case he has selected, but there are many exceptions to it. The extensors of the thigh, foot, and jaw are decidedly predominant; and, according to Adelon, experiments, instituted by Regnier with his dynamometer, make the extensors some kilogrammes more powerful than the flexors.

In our various attitudes, the movements of flexion certainly prevail largely; but as the power of contraction is regulated by volition, it is unnecessary to inquire, whether there be any physical predominance in the flexors over the extensors, as has been attempted by Richerand. We have already seen, that we can in no way attain a knowledge of the degree of force, which any one muscle of the body is capable of developing.

OF THE ATTITUDES.

The attitudes, which man is capable of assuming, are of different kinds. They may all, however, be reduced to two classes—the *active* and the *passive;* the former, including those that require a muscular effort; and the latter comprising only one variety,—that in which the body is extended horizontally on the soil, and where no effort is necessary to maintain its position.

We shall begin with the most ordinary attitude;—that of *standing on both feet.*

This requires considerable muscular effort to preserve equilibrium. The base of sustentation—being the space comprised between the feet plus that occupied by the feet themselves—is small; whilst the centre of gravity is very high.

The body, again, does not consist simply of one bone, but of many; all of which have to be kept steady by muscular effort; and it is necessary that the vertical line shall fall within the base of sustentation, in order that equilibrium may be preserved.

That standing is the effect of the action of the different extensors is proved by the fact, that if an animal be killed suddenly, or stunned, so that volition is no longer exerted over the extensors, he immediately falls forward.

The head, which is intimately united with the atlas or first vertebra of the neck, forms with it a lever of the first kind, the fulcrum of which is in the articulation of the lateral parts of the atlas and vertebra dentata; whilst the power and the resistance occupy the extremities of the lever; and are situated—the one at the face, the other at the occiput.

The fulcrum being nearer the occiput than it is to the anterior part of the face, the head has a tendency to fall forwards. This can be readily seen by supporting a skull on the condyles; yet Mr. Abernethy affirms, that "the condyles are placed so exactly parallel in the centre of gravity, that when we sit upright, and go to sleep in that posture, the weight of the head has a tendency to *preponderate equally* in every direction, as we see in those who are dozing in a carriage." In the living subject, the preponderance anteriorly is not as great as it is in the skeleton, because the greater part of the encephalon is lodged in the posterior portion; but the fact, that when we go to sleep in the upright position, the head drops forwards, is sufficient evidence that it still exists; and that in the waking state the head is kept in equilibrium on the vertebral column by the contraction of the extensor muscles of the head, which are situated at the back part of the neck, and are inserted into the head;—as the splenius, complexus, trapezius, and posterior recti. These muscles are inserted perpendicularly into the lever or bone to be moved, which is an advantage, and some compensation for the shortness of the arm of the lever by which they act.

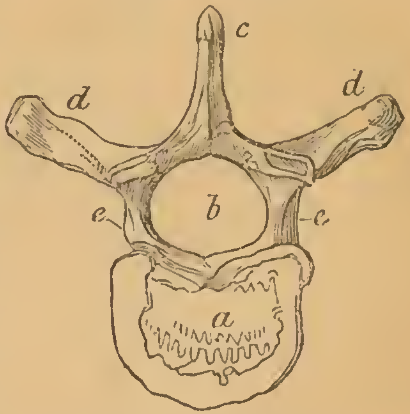
In quadrupeds, the head, not being in equilibrium on the spine, these muscles are very large and strong; the spinous and transverse processes of the vertebræ and the occipital depressions are larger; and, in addition, they have a strong ligament—the *posterior cervical* or *ligamentum nuchæ*—which extends from the spinous processes of the vertebræ to the occiput, and aids in supporting the head.

The vertebral column supports the head, and transmits the weight to its lower extremity. The tendency of the column is to bear forwards: the upper limbs; the neck; the thorax with its contents; the greater part of the contents of the abdomen; and the head itself, by reason of its tendency to fall forwards, all either directly or indirectly, exert their weight on it. Hence the necessity for its great firmness and solidity, which are readily appreciated, if we examine the mode of junction of the different vertebræ, with the strong, ligamentous bands connecting them;—the whole having the form of a pyramid, whose base rests upon the sacrum, with three curvatures in opposite directions, which give it more resistance than if it were straight, and enable it, to support very heavy burdens, in addition to the weight of the organs pressing upon it.

The tendency of the spine to fall forward is resisted by the extensor muscles, which fill the vertebral fossæ or gutters—the sacrolumbalis, longissimus dorsi, multifidus spinæ, &c. which pass from the sacrum to the lower vertebræ of the spine, and from the lower to the upper. Each vertebra, in this action, constitutes a lever of the first kind; the fulcrum of which is in the intervertebral cartilage, the power in the ribs, and other parts that draw the body forwards, and the resistance in the muscles attached to the spinous and transverse processes.

The vertebral column, regarded as a whole, may be considered a lever of the third kind; the fulcrum of which is in the union between the last lumbar vertebra and the sacrum, the power in the parts drawing the spine forwards, and the resistance in the muscles of the back. It is on the lower part of the lever that the power acts most forcibly; and it is there, that the pyramid is thicker; and that the spinous and transverse processes are larger, and more horizontal. We can, accordingly, comprehend why fatigue should be experienced in the loins and sacrum, when we have been, for a long time, in the erect attitude.

Fig. 83.



a. Body of a dorsal vertebra.
b. Canal for containing the spinal marrow.
c. Spinous process.
d d. Transverse processes.
e e. Articulating processes.

It need scarcely be said, that the longer and more horizontal the spinous processes, the greater will be the arm of the lever; and the less the muscular force necessary to produce a given effect.

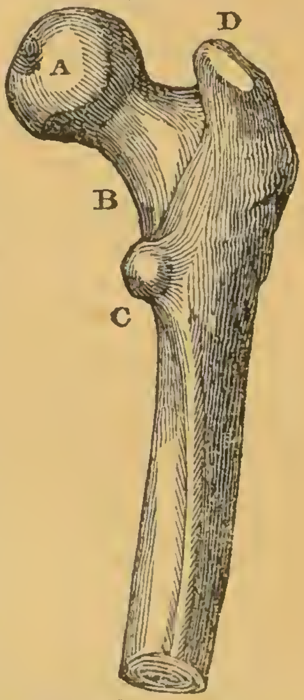
The weight of the whole of the upper part of the body is transmitted to the pelvis; which, resting upon the thigh bones as upon pivots, represents a lever of the first kind, the fulcrum of which is in the ilio-femoral articulations; the power and resistance being situated before and behind.

The pelvis supports the weight of a part of the abdominal viscera; and the sacrum that of the vertebral column, which, by reason of its shape, transmits the weight equally to the ossa femorum, through the medium of the ossa ilii. When the pelvis is, therefore, in equilibrium on the heads of the thigh bones, this is owing to many causes. The abdominal viscera, pressing upon the anterior part of the pelvis, which is naturally inclined forwards, tend to depress the os pubis; whilst the vertebral column, by its weight, tends to press down the sacrum. As the weight of the latter is much more considerable than that of the former, muscles would seem to be required to keep it in equilibrium, as well as muscles passing from the femur to be inserted into the os pubis by the contraction of which the excess of weight of the vertebral column might be counterbalanced. Such muscles do exist, but, as Magendie remarks, they are not the great agents in producing the equilibrium of the pelvis on the thigh bones; for the pelvis, instead of having a tendency to be depressed posteriorly, would appear to bear forwards, inasmuch as the muscles, that resist the tendency which the spine itself has to bear forwards, have their fixed point on the pelvis; and, consequently, exert a considerable effort to draw it upwards.

The strong glutæi muscles, which form the nates, and are inserted into the os femoris, are the great agents of the equipoise; and as the hip-joint is nearer to the pubis than it is to the sacrum, these muscles act with a greater leverage.

The thigh bones transmit the weight of the trunk to the tibia; and here we see the advantage of the neck of the thigh bone, which, as represented in Fig. 84, B, joins the shaft of the bone at a considerable angle. The trochanters D and C are for muscular attachments; and are, of course, advantageous to the muscles, which are inserted into them. The cervix femoris directs the head of the bone A obliquely upwards and inwards, so that, whilst it supports the vertical pressure of the pelvis, it resists the separation of the ilia, which the pressure of the sacrum, with its superincumbent weight, has a tendency to produce.

Fig. 84.



But another and important advantage is, that of affording additional strength in adventitious circumstances. When we are standing perfectly erect, the necks of the thigh bones are very oblique, compared with the line of direction of the body; but if we are thrown forcibly to one side, the line of direction of gravitation corresponds more nearly with that of the neck of the thigh bone, and fracture is rarely produced in this manner. The most common cause of fracture of the neck of the thigh bone is, slipping off a curbstone in towns, or unexpectedly slipping from a slight elevation, with one foot, upon a firm substance beneath, and the fracture, in such case, is generally transverse.

The advantage of this arrangement of the neck of the thigh bone has been compared not inaptly to that resulting from the *dishing* of a wheel; or the oblique position of the spokes from the nave outward to the felly, which strengthens the wheel so essentially, against the strains produced by the wheel sinking with force into a rut or other hollow. (See Fig. 64, and the plates of the skeleton.)

The femur transmits the weight of the body to the large bone of the leg—the tibia; but, from the mode in which the pelvis presses upon it, its lower extremity has a tendency to bear forwards. This is prevented by the action of the extensors of the leg—the rectus and triceps cruris—whose power is augmented by the presence of the patella, a sesamoid bone, seated behind their tendon. The muscles of the posterior part of the leg, which are attached to the condyles of the thigh bone, aid also in preserving this equilibrium.

The tibia is the sole agent for the transmission of the superincumbent weight to the foot. Its upper extremity has, however, a tendency to bear forwards like the lower part of the os femoris. This is prevented by the contraction of the gastrocnemii, tibialis posticus, and the other muscles on the posterior part of the leg.

The foot sustains the whole weight of the body; and its shape and structure are well adapted for the purpose. The sole has some extent, which contributes to the firmness of the erect attitude. The skin and epidermis are thick; and beneath the skin is a thick, adipous stratum, in greater quantity at the parts of the foot which come in contact with the soil. This fat forms a kind of elastic cushion, adapted for deadening or diminishing the effect of pressure.

The whole of the sole of the foot does not come into contact with the ground. The weight is transmitted by the heel, the outer margin, the part corresponding to the anterior extremity of the metatarsal bones, and the extremities or pulps of the toes.

The tibia transmits the weight to the astragalus; and, from this bone, it is distributed to the others that compose the foot; but the heel conveys the largest share.

When the foot rests upon a flat surface, it is entirely passive; but when it is upon a slippery soil, the flexors of the toes, especially of the great toe, are firmly contracted, so as to fix the shoe, as far as possible, and render the attitude more stable. The use of shoes interferes largely with the exercise of the toes, which, in the savage, are capable of diversified and considerable action.

The use of the fibula is, to serve, as its name imports, the purpose of a clasp. The tibia exerts its pressure chiefly towards the inner part of the foot, and, consequently, were it not for the fibula, which passes down below the articulation, dislocation outwards would be constantly menacing us. The fibula has no participation in the transmission of the weight to the ground.

The conditions for equilibrium, as applicable to man, have been already indicated. If the base of sustentation be rendered extensive in any one direction, by widely separating the feet, the attitude is more firm in one direction, but less so in the other. It is as firm as possible in every direction, when the feet are turned forwards in a parallel manner, and are separated by a space equal to the length of one of them.

Whatever diminishes the base of sustentation, diminishes, in like proportion, the stability of the erect attitude. Hence the difficulty of walking on stilts or on wooden legs, on the toes, tight rope, &c.

It seems, that the inhabitants of Les Landes, in the south-west of France, are enabled by habit to use stilts with singular facility. The sandy plains, that bear this name, afford tolerable pasturage for sheep; but, during one part of the year, they are half covered with water; and during the remainder, they are very unfit walking ground, on account of the deep, loose sand and thick furze. The natives, in consequence, habituate themselves to the use of stilts or wooden poles, the former of which are put on and off as regularly as the other parts of their dress. With these they walk readily over the loose sand or through the water, with steps eight or ten feet long.

The difficulty, in this kind of progression, does not arise solely from the smallness of the base of sustentation, but from the greater height to which the centre of gravity is thrown, which renders the equilibrium unstable.

Standing on one foot is necessarily more fatiguing, as it requires the strong and sustained contraction of the muscles, which surround the hip-joint, to keep the pelvis in equilibrium on the os femoris; especially as the body has a strong tendency to fall to the side that is unsupported. The muscles, that prevent the trunk from falling in this direction, are the glutæi, the gemelli, the tensor vaginæ femoris, the pyramidalis, the obturators and the quadratus femoris. The use of the neck of the thigh bone and of the great trochanter is here manifest.

The base of sustentation, in this case, is the space, occupied by the foot in contact with the soil simply; and it need hardly be said, that if this be still farther diminished, by attempting to stand on the toes, the attitude cannot be sustained.

In the *attitude on the knees*, the centre of gravity is brought lower, but the base of sustentation is smaller than on the feet. The patella has to bear the chief pressure; and as it is not provided with such a fatty cushion as exists at the sole of the foot, the position becomes painful and the surface soon abraded. These remarks apply to the case, in which the knees only come in contact with the soil. When the feet are allowed to touch by the points of the toes, the attitude is much more easy and firm, as the base of sustentation is largely augmented,—comprising the space between the knees and toes plus the space occupied by those parts.

The *sitting posture* admits of variety, and is easily intelligible. In every variety in which the back is unsupported, the weight of the body is conveyed to the soil by the pelvis; and the broader this base the firmer the attitude.

When we sit upon a stool without any back, and with the legs raised from the ground, the whole of the weight is conveyed by the parts in contact with the seat: but if the feet touch the ground, the weight of the lower extremities is transmitted to the soil by the feet, whilst the pelvis transmits that of the upper part of the body. In both these cases, if the attitude be long maintained, fatigue is felt in the back, owing to the continued action of the extensor muscles in keeping the body erect.

Sitting in an ordinary chair differs somewhat, in part of the body being supported. Fatigue is then felt in the neck, which is unsupported, and requires the sustained contraction of the extensor muscles of the head.

To support all the parts, as far as possible, the long-backed chairs have been introduced, which sustain the whole body and head; and, by being provided with rockers, a position approaching to the easiest of all attitudes can be assumed. To produce a similar effect in a common chair, the body is often thrown back until the chair rests on its hinder legs only. When the feet of the individual are on the ground, this position is stable; the base of sustentation being large, and comprised between the legs of the chair and the feet of the individual, added to the space occupied by the parts themselves, that are in contact with the soil; but as soon as he raises his feet, the equilibrium is destroyed from the impracticability of making the vertical line fall within the base of sustentation, which is now reduced to the space occupied by the legs of the chair plus the space between them.

In all the varieties of the sitting posture, equilibrium is facilitated by the centre of gravity being brought nearer to the ground.

Lastly. The *horizontal posture* is the only one, that requires no muscular effort. Hence it is the attitude of repose and of the sick and the feeble. The base of sustentation is here extremely large; and the centre of gravity very low. Accordingly, the attitude can be maintained for a long time; the only inconvenience being, that which results to the skin from prolonged pressure on those parts that chiefly convey the weight to the bed,—as the back of the pelvis, the region of the great trochanter, &c.—an inconvenience, which attracts the attention of the physician, more or less, in all protracted and consuming maladies.

The reason, why we prefer soft, elastic beds, is not simply to directly prevent abrasion of those parts of the body that are most exposed to pressure, but to enable a greater portion of the body to transmit the weight; and thus to occasion a more equable partition of the pressure.

There are numerous other attitudes, which may be assumed; as, that upon one knee, on the head, astride, &c.; but they do not merit explanation, their physiology being obvious after what has been said.

OF THE MOVEMENTS.

The movements, of which the body is susceptible, are of two kinds—*partial* and *locomotive;* the former simply changing the relative situation of parts of the body; the latter the relation of the whole body to the soil.

Many of the partial movements constitute an inherent part of the different functions, and are considered under those heads.

In the erect attitude, whilst the body holds the same correspondence with the soil, the position of the upper parts of the body may be varied in all directions, provided the vertical line falls within the base of sustentation. Accordingly, to produce this effect, if the upper part of the body be inclined in one direction, the lower part will have to be thrown more to the opposite.

The head may be turned forwards, backwards, or to one side; and it is capable of a rotatory motion to the right and left. The three first movements occur in the articulation of the occipital bone and atlas, when they are slight; but if to a greater extent, the whole of the cervical vertebræ participate in them. The rotatory motion is effected essentially in the articulation between the first and second vertebræ; the latter of which has an arrangement admirably adapting it for this purpose. A tooth-like or *odontoid* process arises from its anterior part, on which the posterior surface of the anterior part of the atlas or first vertebra turns as on a pivot. This arrangement has obtained the second vertebra the name *vertebra dentata:* and its function, that of *axis.* Rotation to the right is effected by the contraction of the left sterno-mastoid and splenius and of the right complexus, to the left by the action of the opposite muscles of the same name.

The motions of the head aid the senses of sight, hearing, and smell; and are useful in the production of the different vocal tones, by occasioning elongation or decurtation of the trachea and vocal tube. They are, likewise, inservient to expression.

The spine, as a whole, and each of the vertebræ composing it, are capable of flexion, extension, lateral inclination, and circumduction. These motions occur in the fibro-cartilages between the vertebræ; and they are more easy and extensive, in proportion to the thickness and width of the cartilages. This is one cause, why the motions of the cervical and lumbar portions of the vertebral column are freer than those of the dorsal.

The *invertebral substances* or *fibro-cartilages* possess a remarkable degree of elasticity. They yield somewhat, however, to prolonged pressure; and hence, after long continuance in the erect attitude, our stature may be sensibly curtailed. We can thus understand, that at night we may be shorter than in the morning. Buffon asserts, that the son of one of his most zealous *collaborateurs,* M. Guéneau de Montbeillard,—a young man of tall stature,—lost an inch and a half after having danced all night. The loss must be partly ascribed to the condensation of the adipous tissue beneath the foot.

During the flexion of the spine, these cartilages are depressed on the side of the flexure, but they rise on the other; and, by their elasticity, they are important agents in the restoration of the body to the erect position. Where they are thickest the greatest extent of motion is permitted, and this is a cause, why the spine admits of the greatest motion anteriorly. In rotation, the whole is pressed upon and undergoes elongation in the direction of its constituent laminæ. In old age, the cartilages become shrivelled; and this, with the loss of muscular power, is one of the causes why old people bend forwards.

When we assume different positions with the trunk, the centre of motion of the vertebræ becomes modified. If we bend forwards, it is thrown to the anterior part of the body of the vertebræ, if to one side, to the articulating processes, &c. Each vertebra, we have seen, is a lever of the first kind; and as the centre of motion becomes altered the leverage must be so likewise. It is when the body has been bent forwards, and the object is to restore it to the erect position, that the power acts with the greatest advantage,—the fulcrum being thrown to the anterior part of the body of the vertebra, and the arm of the power being the distance between this point and the extremity of the spinous process, into which the power is inserted.

Each vertebra has but a slight degree of motion; but the sum of all their motions is considerable; and it is estimated by multiplying the single motion by the number of vertebræ. The result, however, can only be regarded as approximate, as the extent of motion, of which the different vertebræ are capable, necessarily varies.

The arrangement of the spinous processes of the vertebræ—especially of the *dorsal*—prevents any considerable flexion of the body backwards: and when we find the tumbler bending his body back until his head touches his heels, it is owing to the arrangement of the spine having been modified, in early life, by constant efforts of this kind, until they are no longer obstacles to the movement.

The motions of the vertebræ are frequently united to those of the pelvis on the thigh bones, so that they seem to be more extensive than they really are. This is the case, when we make a low bow.

The motions of the spine are inservient to those of the head, and of the superior and inferior extremities.

The upper limbs are capable of various motions; some of which have been already described, and others will be, hereafter. They are useful in the different attitudes; and, at times, by transmitting to the soil a part of the weight of the body, and thus enlarging the base of sustentation; as when we employ a stick, rest on the hands and knees, or support the head on one or both elbows. They are of great use, likewise, in preserving equilibrium when we walk on a very narrow base; serving in part the purpose of the pole, employed by the dancer on the tight rope.

The lower extremities are, of course, locomotive organs; but they are susceptible of partial movements, likewise; as when we kick with one foot, try the consistence of the ground, cross the legs, tread the foot-board of the lathe, &c.

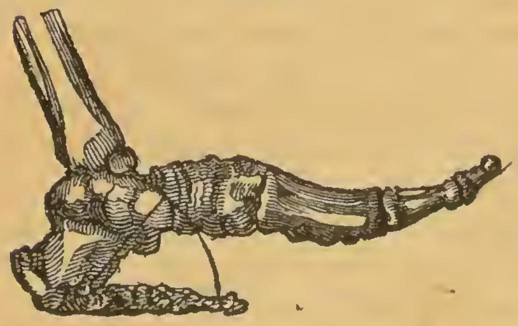
Thus much for the attitudes. We shall now consider the mode in which the relation of the body to the soil is altered, comprising the physiology of walking, leaping, running, swimming, flying, &c. which constitute the different varieties of locomotion or progression.

LOCOMOTIVE MOVEMENTS.

Walking.

Walking is a motion on a fixed surface, the centre of gravity being alternately moved by one of the extremities and sustained by the other, without the latter being, at any time, completely off the ground. It consists of a succession of steps, which are effected—in the erect attitude and on a horizontal surface—by bending one of the thighs upon the pelvis and the leg upon the thigh, so as to detach the foot from the ground by the general decurtation of the limb. The flexion of the limb is succeeded by its being carried forward; the heel is then brought to the ground, and, successively, the whole of the inferior surface of the foot. If the bones of the leg were perpendicular to the part which first touches the ground, we should experience a jolt, but, instead of that, the foot descends in an arc of a circle, the centre of which is the point of the heel.

Fig. 85.



In order that the limb shall be thus carried forward, the pelvis must have described a movement of rotation, on the head of the thigh bone of the limb, which has not been moved, and have carried forward the corresponding side of the body. As yet, only one limb has advanced. The base of sustentation has been modified, but there has been no progression. The limb, remaining behind, has now to be raised and brought forward, so as to pass the other, or to be on the same line with it, as the case may be; and this finishes the *step*. In order to bring up the limb, which is behind, the foot must be successively detached from the soil, from the heel to the toe. In this way, an elongation of the limb is produced, which assists in advancing the corresponding side of the trunk, and excites the rotation of the pelvis on the head of the thigh bone first carried forward. A succession of these movements constitutes walking; the essence of which consists in the heads of the thigh bones forming fixed points, on which the pelvis turns alternately, as upon a pivot, describing arcs of circles, which are more extensive in proportion to the size of the steps.

Walking in a straight line requires, that the arcs of circles described by the pelvis, and the extension of the limbs when carried forward, shall be equal; otherwise, the body will be directed towards the side opposite to that of the limb, whose movements are more extensive. Without the aid of vision, it would be impracticable for us to make the arcs equal; or, in other words, to walk straight forward.

Walking backwards differs somewhat from this. The step is commenced by bending the thigh upon the pelvis, and, at the same time, the leg upon the thigh. The extension of the thigh on the pelvis succeeds, and the whole limb is carried backwards, the leg is afterwards extended upon the thigh, the point of the foot is brought to the ground, and the remainder of its under surface in succession. The other foot is then raised on its point, by which the corresponding limb is elongated; the pelvis, being pushed backwards, makes a rotation on the limb which is behind, and is, by the action of appropriate muscles, carried on a level with, or behind, the other, to afford a new pivot in its turn.

Walking laterally is different from the two last in no arcs being described. In this case, one of the thighs is first slightly bent upon the pelvis, in order to detach the foot from the ground; the whole limb is then moved away by the action of the abductors, and is brought down to the ground. The other limb follows.

If we walk up hill, the fatigue is much augmented; because the flexion of the limb, first carried forward, has to be more considerable; and the limb, that remains behind, has not only to cause the pelvis to execute the movement of rotation, but it has to raise the whole weight of the body, in order to transport it upon the limb, which is in advance. To aid in throwing the weight forwards, the body is bent forward, so that the centre of gravity may be as favourably disposed as possible; and the extensor muscles of the leg carried forward are powerfully contracted to raise the trunk; hence, the feeling of fatigue, which we experience in the knee and anterior part of the thigh, on ascending a long flight of stairs. Fatigue is likewise felt in the calf of the leg, on account of the strong efforts developed in extending the foot, and projecting the body forwards.

Walking down hill is, also, more fatiguing than on the level ground. In this case, there is a tendency in the body to fall forwards; great effort is, consequently, required to keep the vertical line within the base of sustentation, and, accordingly, the muscles, employed in the extension of the head and vertebral column, experience fatigue.

In all these kinds of progression, the character of the soil is a matter of importance. It must be firm enough to afford support to the limb, that presses upon it, otherwise fatigue is experienced, and progression is slow and laborious. This occurs, whenever the soil is too soft or too smooth; the former yielding to the foot, and the latter presenting no inequalities, by which the foot can attach itself. The soil, too, has some influence, in particular cases, by virtue of its elacticity. Such, at least, is the opinion of Borelli; but Barthez thinks, that the influence of the soil is limited to the degree in which it furnishes a firm support. If the soil, again, be movable, as the deck of a vessel, the line of gravity is apt to fall outside the base of sustentation; and to avoid this, the base of sustentation is enlarged by separating the legs so as to give a characteristic air to the gait of the mariner;—and, lastly, if the base be very narrow, as on the tight rope, the steps are obliged to be rapid, and the arms are aided—in modifying the centre of gravity, as may be required—by the use of a long and heavy pole.

Leaping.

In the action of leaping, the whole body is raised from the ground; and is, for a short period, suspended in the air. It consists, essentially, in the sudden extension of the limbs, after they have undergone an unusual degree of flexion. Leaping may be effected directly upwards, forwards, backwards, or laterally.

In the ordinary case of the vertical leap, the head is slightly bent on the neck; the vertebral column is curved forwards; the pelvis is bent upon the thigh; the thigh upon the leg; and the leg upon the foot; the heel generally pressing but lightly on the soil, or not touching it at all. This state of general flexion is suddenly succeeded by a quick extension of all the bent joints; so that the different parts of the body are rapidly elevated, with a force surpassing their own gravity, and to an extent dependant upon the force developed.

In this general muscular movement, the muscles, that form the calf of the leg, and are inserted into the heel, have to develope the greatest force, inasmuch as they have to raise the whole body, and to give it the impulse, which surmounts its gravity. They are, however, favourably circumstanced for the purpose; being remarkably strong; inserted perpendicularly into the heel; and having the advantage of a long arm of a lever.

Figure 82 will show, that whenever the body is bent in the position it assumes preliminary to a leap, opposite impulses must be communicated, by the restoration of the different parts to the vertical line B F. The leg B will tend to impel the body backwards, by following the curved line C G. C D, on the other hand, by describing the curve D I, will tend to impel it forward; whilst the head and trunk, represented by the line D E, will describe the curve E F, and give an impulse backwards. Every vertical leap must, therefore, be a mean between these different impulses, or rather the backward and forward impulses must destroy or neutralize each other; and that which is concerned in the elevation of the trunk be alone effective.

In the forward leap, the movement of rotation of the thigh predominates over the impulses backward, and the body is projected forward. On the other hand, the impulses of the vertebral column, and of the leg on the foot prevail in the backward leap. The length of the lower limbs is favourable to the extent of the leap. The forward leap, in particular, is greatly dependant upon the length of the femur, the part in which the forward impulse is situated.

It does not appear, that any kind of impulse is communicated to the body by the surface on which we rest, at the moment of leaping, unless it be very elastic. In this last case, however, its reaction is added to the effort of the muscles, that occasion the elevation of the body; hence, the wonderful leaps of the performers in our circuses and on the tight rope. On the other hand, if the soil do not afford the necessary resistance, and yields to the feet, leaping is almost or wholly impracticable.

The upper extremities are not without their use in leaping. They are brought close to the body, whilst the joints are bent, and are separated from it, at the moment when the body leaves the soil. By being held firmly in this manner, they allow the muscles, that pass from the os humeri to the trunk, to exert a degree of traction upwards, and thus to assist the extensors of the foot in the projection of the body. It is with this view, that the ancients employed their ἁλτηρες, (*halteres* or *poisers*) in leaping; and that the moderns use bricks, stones, or other solid, heavy bodies, with a like intent. It is, likewise, manifest, that by steadying the arms, and then moving them rapidly backwards, a backward impulse may be given to the upper part of the trunk.

The effect of a run, before we leap, is to add to the force—developed by muscular contraction—that of the impulse acquired by the body whilst running. The leap is, under such circumstances, necessarily more extensive.

Some of the smaller animals surprise us by the extent of their leap. The *jumping maggot*, found in cheese, erects itself upon its anus, forms its body into a circle, by bringing its head and tail into contact, and, having contracted every part as much as possible, it unbends with a sudden jerk, and darts forward to an astonishing distance. Small animals, indeed, leap much farther than the larger, in proportion to their size; and as Mr. Sharon Turner has remarked, in his 'Sacred History of the World,' exhibit muscular powers still more superior to those of the greatest animals than their comparative minds. He has given some amusing representations of this difference:—for example, Linnæus observes, that if an elephant were as strong in proportion as a stag beetle, he would be able to tear up rocks and to level mountains. A cock-chafer is, for its size, six times as strong as a horse. The flea and the locust leap two hundred times their own length, as if a man should leap three times as high as St. Paul's. The cuckoo-spit frog-hopper will sometimes leap two or three yards, which is more than two hundred and fifty times its own length, as if a man should vault at once a quarter of a mile. Mouffet relates, that an English mechanic made a golden chain as long as a finger, with a lock and key, which was dragged by a flea: and Latreille mentions a flea, of moderate size, dragging a silver cannon on wheels, that was twenty-four times its own weight. This cannon was charged with powder and fired, without the flea seeming to be alarmed.

Running.

This variety of progression consists of a series of low leaps, performed by each leg in alternation. It differs from walking, in the body being projected forward at each step, and in the hind foot being raised before the fore-foot touches the ground. It is more rapid than the quickest walk, because the acquired velocity is preserved and increased, at each bound, by a new velocity. Running, therefore, cannot be instantaneously suspended, although a stop may be put to walking at any moment.

In running, the body is inclined forward, in order that the centre of gravity may be in a proper position for receiving an impulse, in that direction, from the hind leg; and the fore leg is rapidly advanced, to keep the vertical line within the base of sustentation; and thus to prevent the body from falling. There is, consequently, in running, a moment in which the body is suspended in the air.

Swimming.

Although Magendie affirms, that the human body is, in general, specifically heavier than water, and that consequently, if left to itself in a considerable quantity of that fluid, it would sink to its lowest portion, the question respecting its specific gravity has not been rigorously determined; and many eminent practical philosophers have even held an opinion the reverse of that of Magendie. Borelli accords with him; and a writer of a later period,—Mr. Robertson, who details a set of experiments, on this subject, in the fiftieth volume of the *Philosophical Transactions*,—seems to have originally coincided with him also. He weighed, however, ten different individuals in water, comparing their weight with that of the fluid displaced by their bodies; and he affirms, that, with the exception of two, every man was lighter than his equal bulk of fresh water, and much more so than his equal bulk of sea water;—"consequently," he says, "could persons, who fall into water, have presence of mind enough to avoid the fright, usual on such accidents, many might be preserved from drowning." In corroboration of this inference, Mr. Robertson relates a circumstance connected with his own personal knowledge. A young gentleman, thirteen years of age, little acquainted with swimming, fell overboard from a vessel in a stormy sea; but having had presence of mind enough to turn immediately upon his back, he remained a full half hour, quietly floating on the surface of the water, until a boat was lowered from the vessel. He had used the precaution to retain his breath, whenever a wave broke over him, until he again emerged.

A case is given in the Rev. Mr. Maude's *Visit to Niagara*, in 1800, which is strikingly corroborative of Mr. Robertson's view of this matter. The author was on board a sloop on Lake Champlain, when a boy, named Catlin, who was on deck cutting bread and cheese with a knife, was knocked overboard by the captain jibbing the boom. He missed catching hold of the canoe, which was dragging astern, and an attempt of Mr. Maude's servant to untie or cut the rope, which fastened it, that it might drift to his assistance, also failed. Catlin was known to be unable to swim. It was in the night and very dark, and it was with difficulty, that the captain, who considered that there was no hope of saving his life, was at last prevailed upon to go in the canoe to attempt it. He succeeded, however, in picking the boy up, and brought him on board again in about a quarter of an hour. "Catlin's relation," proceeds Mr. Maude, "almost exceeds probability. He had heard my exclamation to seize the canoe, which he was on the point of doing, when it gave a sudden swing and baffled him; but, finding he could support his head above water, he dismissed all fear, expecting that the canoe would come every moment to his assistance. When he no longer heard our cheers from the sloop, hope began to fail him, and he was on the point of resigning himself to a watery grave, when he heard the captain's life-restoring voice. On telling Catlin that we despaired of his safety, as we understood that he could not swim, he replied, 'nor can I. I was never before out of my depth; but I am fond of bathing, and have often seen lads what they call tread the water, and that's what I did.' The truth of this account was made manifest, by the boy not only retaining his hat on his head, but its being perfectly dry; and what adds to the singularity of this event, the boy never quitted his grasp of the knife, that he was eating his bread and cheese with."

Knight Spencer found, that he was buoyant on the surface of the sea, when he held stones, weighing six pounds avoirdupois, in his hands. In the water, however, the stones lost two pounds five ounces in weight, so that he was really freighted with no more than three pounds eleven ounces. He himself weighed one hundred and thirty pounds.

Dr. Franklin, again, whilst he considers the detached members of the body, and particularly the head, as of greater weight than their bulk of water, acknowledges the body, in the aggregate, to be of less specific gravity, by reason of the hollowness of the trunk. He thinks, that a body, immersed in water, would sink up to the eyes, but that if the head were inclined back, so as to be supported by the water, the mouth and nostrils would remain above,—the body rising one inch at every inspiration, and sinking one inch at every expiration; and also, that clothes give little additional weight in the water, although, in stepping out of it, the case is quite otherwise. He concludes, therefore, if a person, could avoid struggling and plunging, that he might remain in the posture described with safety. That the body is to a certain degree buoyant he refers to the experience of every one, who has ever attempted to reach the bottom of deep water, the effort required sufficiently proving, that something resists our sinking.

The truth would appear to be, that there is only a slight difference between the specific gravity of the human body and that of water; but that the former is something greater, otherwise there would be no reason, why the dead body should sink to the bottom, as it is known to do. The old notion was, that, in the living state, the specific gravity of the body is decidedly less; but that, in death from drowning, a quantity of water always enters the lungs and stomach, and that thus, these cavities, being no longer occupied with air, the buoyancy is lost and the body sinks. Nothing is now better established than that no water gets into the stomach, except what is accidentally swallowed during the struggling, and, that no water must be looked for in the lungs; a quantity of frothy mucus being all that is generally perceptible there. Yet, in courts of justice, the absence of water in these situations has been looked upon as evidence,—where a body has been found in the water,—that death had not occurred from drowning; and attention has, consequently, been directed to other causes, which might have produced it; the presumption being, that the person had been first killed and then thrown into the water for the purpose of averting suspicion.

Another erroneous opinion, at one time prevalent, was, that if a person goes alive into water he will sink; if dead, he will swim; and that, therefore, it is necessary, that some weight should be attached to a body, when committed to the deep, to make it sink.

All these fallacious notions are dwelt upon in a case, deeply interesting to all jurists, medical and others;—that of Spencer Cowper, Esq. a member of the English bar, who, with three other individuals, was tried at the Hertford Assizes, in 1699, for the murder of Mrs. Sarah Stout. The speeches of the counsel, with the evidence of many of the medical witnesses, sufficiently testify the low condition of medico-legal knowledge at that period.

Mr. Jones,—the counsel for the prosecution—affirmed, that "when her (Mrs. Stout's) body came to be viewed, it was very much wondered at; for, in the first place, it is contrary to nature, that any persons, that drown themselves, should float upon the water. We have sufficient evidence," he adds, "that it is a thing that never was: if persons go alive into the water, then they sink; if dead, then they swim." In confirmation of this strange opinion, two seamen were examined, one of whom deposed as follows:—"In the year 89 or 90, in Beachy fight, I saw several thrown overboard, during the engagement, but one particularly I took notice of, that was my friend and killed by my side. I saw him swim for a considerable distance from the ship, &c. Likewise in another engagement where a man had both his legs shot off and died instantly, they threw over his legs; though they sunk, I saw his body float; likewise I have seen several men, who have died natural deaths at sea; they have, when they have been dead, had a considerable weight of ballast made fast to them and so were thrown overboard; because we hold it for a general rule that all men swim if they be dead before they come into the water, and, on the contrary, I have seen men when they have been drowned, that they have sunk as soon as the breath is out of their bodies," &c.—The weights are, however, attached to the dead, when they are thrown into the sea, not for the purpose of facilitating their descent, but to prevent them from rising, when putrefaction renders them buoyant, by the disengagement of air into the splanchnic cavities.

On the same trial, Drs. Coatsworth, Burnet, Nailor, and Woodhouse deposed, that when a person is drowned, water will be taken into the stomach and lungs, and, as none was found in the case of Mrs. Stout, they were of opinion, that she came to her death by other means.

From all that has been said, it would appear, that the great requisite for safety to the inexperienced, who may fall accidentally into the water, is a firm and sufficient conviction of the fact, that the living body naturally floats, or that it can be easily made to do so. This conviction being acquired, no more than a common share of presence of mind would seem to be necessary to insure, that the portion of the body, which is the great outlet of the respiratory organs, shall be above the surface.

The movements, adapted to the progression of the body, are to be acquired in the same manner as a child learns to walk;—proficiency in this, as in everything else, being the result of pratice.

Swimming nearly resembles leaping, except that the effort in it does not take place from a fixed surface. Both the upper and lower extremities participate in it. Whilst the former are brought to a point anterior to the head, and form a kind of cut-water, the lower extremities are drawn up and suddenly extended, as in leaping. The water, of course, yields to their impulse, but not as rapidly as it is struck, and hence the body is projected forwards. The upper limbs are now separated, and carried circularly and forcibly round to the sides of the body, by which the impulse is maintained: the legs are, in the mean time, drawn up; and, by a succession of these movements, progression is effected, the hands and feet being turned outwards to present as large a resisting surface as possible. The chest is, at the same time, kept dilated, to augment the bulk of the body, and, of course, to render it specifically lighter, and the head is raised above the surface to admit of respiration. This action is analogous to that of the propulsion of a boat by oars. The body resembles the boat; and the upper and lower extremities are the oars or sculls.

The practised swimmer can execute almost as many movements in the water as he can on land.

Flying.

If the human body sinks in water, how little can it be susceptible of suspension in the air by its own unassisted muscular powers. It is a mode of progression, which is denied to man; and, accordingly, most of the attempts at flying, since the mythical exploits of Dædalus and Icarus, have been confined to enabling the body to move from one place to another, by means of ropes and appropriate adjuncts. Not many years ago, a native of this country exhibited a curious variety of progression, at Dover, England. He was called the "*flying phenomenon*:" and his plan, so far as we can recollect, was to have a rope extending from the heights to the beach beneath, along which he descended, by means of rings attached to different parts of his person, and which had the rope passing through them.

The sources of difficulty, in flying, are;—the great weight of the body, and the insufficient force, which the muscles are capable of exerting. It is by no means impossible, however, that by some contrivance, of which the lightest gases might form a part, and by an imponderous apparatus, which would enlarge the surface of the upper extremities, progression, in this manner, might be effected;—but to a limited and unmanageable extent, only.

Connected with this subject, we may refer, briefly, to some varieties of muscular action, the nature of which will be easily intelligible.

In *bearing a load*, we have simply a variety of walking in the erect attitude, with this addition, that the extensor muscles of the head, neck, or back,—according to the part on which the burden may be placed,—have to contract forcibly to support it.

The position of the individual has, also, to be so regulated, that the centre of gravity shall be always over the base of sustentation. Hence, if the load be on his back, he leans forward; if borne before him, he leans backward; and this is the cause of the portly and consequential appearance of the corpulent. If the load be on his head, he stands as upright as possible, for a like reason.

In *propelling a body* forwards, either by the hands or shoulders, the feet are firmly fixed on the ground; the limbs are in a state of semi-flexion, and the centre of gravity is directed forwards, so as to aid the force that has to be developed by the muscles. The limbs are then suddenly extended, the body is thrown forward, and the whole power exerted on the obstacle which has to be moved.

On the other hand, when we *drag a weight* after us, or attempt to *dislodge a stake* from the earth; the feet are equally fixed firmly on the ground, but the body is in a state of extension, and is directed as far as practicable backwards, in order that the tendency to fall, owing to the centre of gravity overhanging the base of sustentation, may aid the force that has to be developed by the muscles of the arms, which embrace the substance to be moved, or are attached to it indirectly. The flexor muscles are, then, powerfully contracted, and the whole force is exerted upon the object.

As, in both these cases, there is danger of falling should the body yield suddenly, the feet are so placed as to obviate this, as far as possible; by being separated in the direction in which the force is exerted.

Squeezing consists in laying hold of the object, either between the arms and body, or by the fingers; and then forcibly contracting the flexor muscles.

In all these, and other varieties of strong muscular contraction, the respiration is interrupted, in order that the thorax may be rendered fixed, and serve as an immovable point of origin for the muscles of the head, shoulders, and arms. This is effected by taking in a full inspiration; strongly contracting the respiratory muscles; and, at the same time, closing the glottis to prevent the exit of the air.

Lastly, as organs of *prehension*, the upper extremities are of admirable organization; possessing great mobility; and, at the same time, solidity. The joint at the shoulder allows of extensive motion; and the bones, to which the arm is attached at this joint—the scapula and clavicle—are themselves movable. The forearm is, likewise, susceptible of various movements on the arm, of which those of pronation and supination are not the least important; whilst the hand possesses every requisite for an organ of prehension. It is composed of numerous bones, and is capable of being applied to the most irregular surfaces. The great superiority of the human hand arises, however, from the size and strength of the thumb, which can be brought into a state of opposition to the fingers; and is, therefore, of the highest use in enabling us to seize hold of, and grasp spherical bodies; to take up any object; to lay a firm hold of whatever we seize, and to execute the various useful, and ornamental processes of the arts. These processes require the most accurate, quick, and combined movements of the muscles. How quick, for example, is the motion of the hand in writing, and in executing the most rapid movements on the piano-forte! How accurate the muscular contraction, which stops the precise part of the violin-string to bring out the note or semi-tone in the most *allegro* movements; and what a multitude of combinations must be invoked in all these cases!

As an organ of touch, the advantages of the upper extremity have already been depicted; and much of what was then said applies to it as an organ of prehension. "In this double respect," observes

Adelon, "man is the best provided of all animals. How much, in fact, does he stand in need of an ingenious instrument of prehension! As we have several times remarked, he has, in his organization, neither the offensive nor defensive arms, that are bestowed on other animals. Naked from birth, and exposed to the inclemencies of the atmosphere, without means of attack or defence against animals, he must incessantly labour to procure what he requires. It was not, consequently, enough that he should possess an intellect, capable of making him acquainted with, and of appropriating to himself, the universe. He must have an instrument adapted for the execution of all that his intellect conceives. Such instrument is his upper extremity. In short, whilst other animals find everything in nature—necessary for their different wants—more or less prepared, man, alone, is obliged to labour to procure what his require. He must make himself clothes, construct his habitations, and prepare his food. He is the *labouring* and *producing* animal, *par excellence;* and hence he needs not only an intellect to conceive, but an instrument to execute."

OF THE FUNCTION OF EXPRESSION OR OF LANGUAGE.

Under this head will be included those varieties of muscular contraction, by which man and animals exhibit the feelings that impress them, and communicate the knowledge of such feelings to each other.

It comprises two different sets of actions:—those that are addressed to the ear, or the phenomena of *voice:* and those that are appreciated by the senses of sight and touch, or the *gestures.* Of these we shall treat consecutively.

OF THE VOICE.

By the term *voice*—or by *phonation,* which has been proposed by Chaussier—is meant the sound produced in the larynx, whilst the air is passing through it, either to enter, or issue from, the trachea.

Anatomy of the Vocal Apparatus.

The apparatus concerned in the production of the voice, is composed, in man, of the muscles concerned in respiration; of the larynx; and of the mouth and nasal fossæ. The first are merely agents for propelling the air through the instrument of voice. They will fall under consideration when we are on the subject of respiration; whilst the anatomy of the mouth and nasal fossæ have been, or will have to be, described in other places. The larynx, and its primary dependencies, which are immediately concerned in the production of voice, will, therefore, alone engage us at present.

The larynx is situated at the anterior part of the neck, and forms the projection so perceptible in that of the adult male, called *pomum Adami.*

An attentive examination of the various parts which compose the larynx, so far as they concern its physiological relations, will be necessary; and it will exhibit the imperfect knowledge of several writers on the voice, and the false and insufficient views that have been entertained on the subject.

If we look along the larynx, from the trachea, of which it is a continuation, we find that the tube becomes gradually narrower from side to side; and, at length, presents an oblong cleft, called the *glottis*, the sides of which are the essential organ of voice.

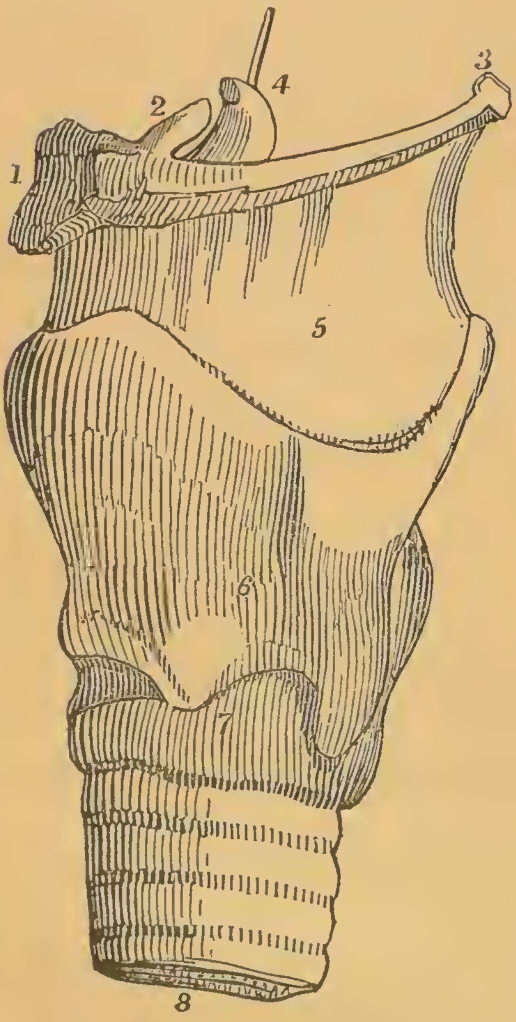
The larynx is composed of four cartilages—the *cricoid*, *thyroid*, and *two arytenoid*. The cricoid is the lowest of these, and is the inferior part of the organ;—that by which it joins the trachea. It is shaped like a ring, whence its name, but is much deeper behind than before. The thyroid is situated above the cricoid, with which it is articulated in a movable manner, by means of its inferior cornua. It is the large cartilage that occupies the anterior, prominent, and lateral part of the larynx.

The arytenoid cartilages are two in number. They are much smaller than the others, and are articulated with the posterior part of the cricoid;—also, in a movable manner. Around this articulation is a synovial capsule,—close before and behind, but loose within and without. Before it, is the *thyro-arytenoid* ligament; and, behind, a strong, ligamentous fascia, called, by Magendie, from its attachments—*crico-arytenoid*. The arrangement of this articulation would appear to permit only of lateral movements of the arytenoid cartilages on the cricoid; all motion anteriorly or posteriorly, or in any other direction, being impracticable. The joint, consequently, is a lateral ginglymus.

Three fibro-cartilages, likewise, form part of the constituents of the larynx. These are—the *epiglottis*, and two small bodies, that tip the arytenoid cartilages, and are met with only in man—the *capitula Santorini* or the *supra-arytenoid cartilages* or the *capitula cartilaginum arytenoidarum*.

On examining the interior of the larynx, we discover, that there are two clefts,—one above the other; the uppermost being usually oblong-shaped, ten or eleven lines long, and two or three broad, having the shape of a triangle, the base of which is forwards. It is circumscribed, anteriorly, by the thyroid cartilage and epiglottis; posteriorly, by the arytenoid cartilages; and, laterally, by two folds of the mucous membrane, C C, Fig. 88, which pass from the epiglottis to each arytenoid cartilage, and are called the *superior ligaments of the glottis*, and the *superior vocal cords*. A few lines below this is a second cleft, also oblong from before to behind, (4, Figure 87,) and of a triangular shape, the base of which is behind. It is bounded, anteriorly, by the thyroid cartilage; posteriorly, by a muscle extending from one arytenoid cartilage to the other—the *arytedoineus;* and, laterally, by two folds, formed of the thyro-arytenoid ligament, passing from the anterior part of the arytenoid cartilage to the posterior part of the thyroid, and of a muscle of the same name. These folds are called the *inferior ligaments* or *lips of the glottis*, or the *inferior vocal cords.* They are represented by Nos. 3, 3, in Fig. 87; and by B B, Fig. 88.

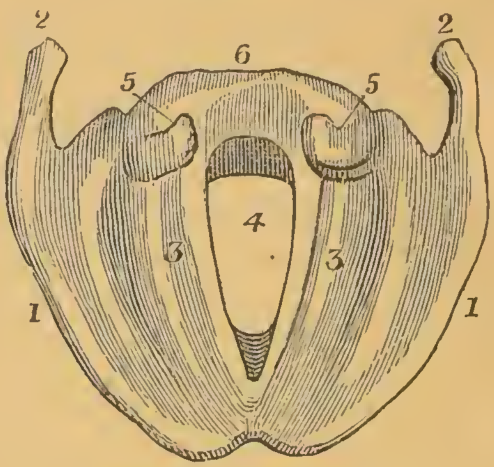
Fig. 86.



Larynx seen externally.

1. Os hyoides.
2. Lesser cornu of do.
3. Greater cornu of do.
4. Extremity of the Epiglottis.
5. Hyo-thyroid membrane
6. Thyroid Cartilage.
7. Cricoid Cartilage.
8. Trachea.

Fig. 87.

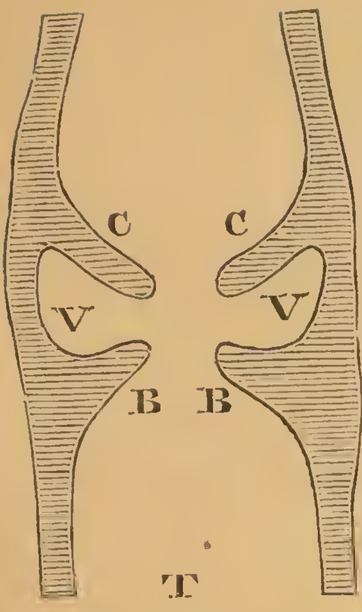


Glottis seen from above.

1 1. Thyroid Cartilage.
2 2. Greater cornu of do.
3 3. Vocal Cords.
4. Glottis.
5 5. Arytenoid Cartilages.
6. Cricoid Cartilage.

Between these two clefts are the *sinuses* or *ventricles of the larynx*, V V, Fig. 88. The inferior, exterior and superior sides of these are formed by the thyro-arytenoid muscle. By means of these ligaments—superior and inferior—the lips of the superior and inferior apertures are perfectly free, and unencumbered in their action.

Fig. 88.



Section of the Larynx.

Anatomical descriptions will be found to give different significations to the word *glottis.* Some have applied it to the upper cleft, some to the lower; some, again, to the ventricles of the larynx; and others to the whole space, comprised between the inferior ligaments and the top of the larynx. It is now, generally perhaps, restricted to the part of the larynx engaged in the production of voice, or usually considered to be so engaged—the space between the inferior ligaments with the ligaments themselves—and in this signification it will be employed by us.

The mucous membrane, which lines the larynx, is continuous, above, with that of the mouth; below, with that of the trachea. It contains several mucous follicles, some of which are agglomerated near the superior ligaments of the glottis and the environs of the ventricles of the larynx, seeming to constitute distinct organs, which have been called *arytenoid glands.* A similar group exists between the epiglottis behind, and the os hyoides and thyroid cartilage before, which has been termed the *epiglottic gland.* The uses of this body are not clear. Magendie conceives, that it favours the frequent slidings of the thyroid cartilage over the posterior surface of the os hyoides; that it keeps the epiglottis separated above from this bone; and, at the same time, furnishes it a very elastic support, which may aid it in the functions it has to execute, connected with voice and deglutition.

The larynx is capable of being moved as a whole, as well as in its component cartilages. It may be raised, depressed, or carried forwards or backwards. The movements, however, which are the most concerned in the production of the voice, are such as are effected by the action of the *intrinsic* muscles, as they have been termed. These are, 1st. The *crico-thyroid,* a thin, quadrilateral muscle, which, as its name imports, passes obliquely from the upper margin of the cricoid cartilage to the lower margin of the thyroid. Magendie affirms, that its use is not, as generally imagined, to depress the thyroid on the cricoid, but to elevate the cricoid and approximate it to the thyroid, and even to make it pass slightly under its inferior margin. 2dly. The *crico-arytenoidei postici,* and the *crico-arytenoidei laterales;* the former of which pass from the posterior surface of the cricoid to the base of the arytenoid; and the latter from the side of the cricoid to the base of the arytenoid cartilages. The use of these muscles is to carry the arytenoid cartilages backwards, separating them at the same time from each other. 3dly. The *arytenoid muscle*—of which there is one only. It extends across from one arytenoid cartilage to the other; and, by its contraction, brings them towards each other. 4thly. The *thyro-arytenoid muscle*, which, according to Magendie, is the most important to be known of all the muscles of the larynx, as its vibrations produce the vocal sound. It forms the lips of the glottis, and Magendie describes it as constituting, also, "the inferior, superior, and lateral parietes of the ventricles of the larynx." Generally, it is considered to arise from the posterior surface of the thyroid cartilage, and the ligament connecting it with the cricoid, and to be inserted into the anterior edge of the arytenoid cartilage. Lastly. The muscles of the epiglottis—the *thyro-epiglotticus* and *aryteno-epiglotticus*, and some fibres that may be looked upon as the *vestiges* of the *glotto-epiglotticus*, which exists in many animals. These muscles,—the position of which is indicated by the name,—by their contraction, modify the situation of the epiglottis.

The intrinsic muscles of the larynx receive their nervous influence from the eighth pair. Shortly after this nerve has issued from the cranium it gives off a branch called the *superior laryngeal*, which is distributed to the arytenoid and crico-thyroid muscles; and, after its entrance into the thorax, it furnishes a second, which ascends towards the larynx, and is, on that account, called the *recurrent* or *inferior laryngeal*. It is distributed, to the crico-arytenoidei postici and crico-arytenoidei laterales, and to the thyro-arytenoid muscles.

In each animal species, the glottis has a construction, corresponding to the kind of voice that has to be elicited; and, when it is examined on a living animal—on dogs for example—it enlarges and contracts alternately, the arytenoid cartilages separating when the air enters the lungs, and approximating during expiration.

To the trachea the larynx is attached by a fibrous membrane, which unites the cricoid with the first ring of the trachea; and, above, it is connected with the os hyoides by a similar membrane—the *hyo-thyroid*, No. 5, Fig. 86, as well as by the thyro-hyoid muscle.

Physiology of the Voice.

The production of the voice requires, that air shall be sent from the lungs, which, in passing through the glottis, may throw certain parts into vibration, and afterwards make its exit by the *vocal tube*,—that is, by the mouth and nasal fossæ.

Simple expiration does not, however, produce it, otherwise we should have the vocal sound accompanying each contraction of the chest. Volition is necessary to excite the requisite action of the muscles of the larynx; as well as of those of respiration; and by it the tone and intensity of the voice are variously modified.

That the voice is produced in the larynx, we have both direct and indirect testimony. An aperture, made in the trachea, beneath the larynx, deprives both man and animals of voice. This occurs also, if the aperture be made in the larynx beneath the inferior ligaments; but if made above the glottis, so as to implicate the epiglottis and its muscles, the superior ligaments of the glottis, and even the upper portions of the arytenoid cartilages, the voice continues. Magendie, and J. Cloquet refer to the cases of two men, who had fistulæ in the trachea; and who were unable to speak unless the fistulous openings were accurately stopped by some mechanical means.

If, again, we take the trachea and larynx of an animal or of man, and blow air forcibly into the tracheal extremity towards the larynx, no sound is produced, except what results from the friction of the air against the sides of the larynx. But if we approximate the arytenoid cartilages, so that they touch at their inner surfaces, a sound will be elicited, bearing some resemblance to the voice of the animal to which the larynx belongs; the sound being acute or grave according as the cartilages are pressed against each other with more or less force; and varying in intensity, according to the degree of force with which the air is sent through it. In this experiment, the inferior ligaments can be seen to vibrate.

Paralysis of the intrinsic muscles of the larynx likewise produces dumbness; and this can be affected artificially. Much discussion at one time prevailed, regarding the effect of tying or cutting the nerves distributed to these muscles. The experiments of Haighton induced him to think, that the recurrent branches of the par vagum supply parts, which are essentially necessary to the formation of the voice; whilst the laryngeal branches seemed to him to affect only its modulation or tone. Subsequent experiments have sufficiently shown, that if both the recurrent nerves and the superior laryngeal are divided, complete aphonia must result. Magendie found, indeed, that when both recurrents,—which, as has been remarked, are distributed to the thyro-arytenoid muscles,—are cut, the voice is usually lost; whilst if one only be divided, the voice is but half destroyed. He noticed, however, that several animals, in which the recurrents had been cut, were still capable of eliciting acute sounds, when labouring under violent pain,—sounds, which were very analogous to those, that could be produced mechanically with the larynx of the dead animal, by blowing into the trachea and approximating the arytenoid cartilages; and this he properly explains by the distribution of the nerves of the larynx. The recurrents being divided, the thyro-arytenoid muscles are no longer capable of contracting, and hence aphonia results; but the arytenoid muscle, which receives its nerves from the superior laryngeal, still contracts, and, during a strong expiration, brings the arytenoid cartilages together, so that the chink or cleft of the glottis is sufficiently narrow for the air to cause vibration in the thyro-arytenoid muscles, although they may not be in a state of contraction.

Again, every part of the larynx, with the exception of the inferior ligaments, may be destroyed, and yet the voice may continue. Bichat split the upper edge of the superior ligaments of the glottis, without the voice being destroyed; and the excision of the tops of the arytenoid cartilages had no more effect. Magendie divided, with impunity, the epiglottis and its muscles, and voice was accomplished, until he cut the middle of the arytenoid cartilages or split the thyroid cartilages longitudinally, when he, of course, destroyed the glottis. Lastly, when the larynx is exposed in a living animal, so that the different parts can be readily seen at the time when voice is accomplished,—the superior ligaments, according to Bichat and Magendie, who have performed the experiment, are manifestly unconcerned in the function, whilst the inferior ligaments distinctly vibrate. These ligaments must, therefore, be regarded as the essential organs of voice.

The deeply interesting, but difficult problem now presents itself;—to determine the precise mechanism of the vibration of those ligaments; and what kind of instrument the vocal organ must be regarded. The latter question, on which, it might be conceived, so much physical evidence must exist, has been the topic of much dissension, and is by no means settled at this day.

Aristotle, Galen, and the older writers in general, looked upon the larynx as a wind instrument of the flute* kind, in which the interior column of air is the sonorous body; the trachea the body of the flute, and the glottis the beak. The air, they conceived, when forced from the lungs, in passing through the glottis or beak, is broken by the inferior ligaments of the larynx; vibrations are, consequently, produced, and these vibrations give rise to the sound.

Fabricius, of Acquapendente, was one of the first to object to this view of the subject. He properly remarked, that the trachea cannot be regarded as the body of the flute, but as a *porte-vent* to convey the air to the glottis. He was of opinion, that the glottis corresponds to the beak of the flute, and that the vocal tube or all that part above the glottis resembles the body of the instrument. Similar opinions, with more or less modification, have been adopted by Blumenbach, Sömmering, Savart, &c.

About the commencement of the last century Dodart laid before the *Académie des Sciences* of Paris, three memoirs on the theory of the voice, in which he considered the larynx to be a wind instrument of the horn, and not of the flute, kind; the inferior ligaments of the glottis being to the larynx what the lips are to the performer on the horn.

In 1741, Ferrein, in a communication, also made to the *Académie des Sciences* maintained that the larynx is a stringed instrument;—the sound resulting from the oscillation caused in what he called the *cordæ vocales*, or the inferior ligaments of the larynx, by the air in

* The flute here alluded to, is the common *flute* or *flute à bec*, in which the *embouchure* is at one extremity.

expiration; and a modification of this view was professed by Dr. Young.

At the present day, the majority of physiologists and natural philosophers regard the larynx as a wind instrument, but of the reed kind; such as the clarionet, hautboy, &c. and they differ chiefly from each other, in explaining the various modifications of the tone and quality of the voice: for almost all are agreed, that it is produced by the vibrations of the inferior ligaments of the glottis. Piorry, and Jadelot consider the glottis to be an instrument *sui generis*, eminently vital, and which, of itself, executes the movements necessary for the production of vocal sounds; but all we know, of the physiology of the production of the voice, is—that the expired air is sent into the larynx by the muscles of expiration,—that the intrinsic muscles of the larynx give to the inferior ligaments sufficient tension to divide the air, and that the air receives the vibrations, whence sound results, which escapes by the vocal tube.

Intensity or strength of the voice.—The strength of a sound depends upon the extent of the vibrations of the body producing it. In the case of the voice, it is partly dependent upon the force with which the air is sent from the lungs, and partly on the size of the larynx. A strong, active person, with a capacious chest and prominent pomum adami,—in other words, with a large larynx,—is of an organization the most favourable for a strong voice. But if this same individual, thus favourably organized, be reduced in strength by sickness, his voice is enfeebled; because, although the formation of his larynx may be favourable, he is incapable of sending the air through it, with sufficient force to excite extensive vibrations of the vocal ligaments.

The voice of the male is much stronger than that of the female, of the eunuch, or of the child. This is greatly owing to his larynx being more developed. The change of the voice in the male at puberty is owing to the same cause; the prominence of the pomum adami, which is first observed at this age, indicating the elongation, which has supervened in the lips of the glottis. As voice is commonly produced, both ligaments of the glottis participate; but if one should lose its power of vibrating, from any cause, as from paralysis of one-half the body, the voice loses, *cæteris paribus*, one-half its intensity. Magendie affirms, that this is manifested by cutting one of the recurrents of a dog.

Tone of the voice.—Nothing can exceed the human organ of voice in variety and execution. Dr. Barclay has endeavoured to calculate the different changes of which it is susceptible, proceeding on the principle, that where a number of movable parts constitute an organ destined to some particular function. and where this function is varied and modified by every change in the relative situation of the movable parts, the number of changes, producible in the organ, must at least equal the number of muscles employed, together with all the combinations of which they are capable. The muscles, proper to the five cartilages of the larynx, are, at least, seven pairs; and fourteen muscles, that can act separately or in pairs, in combination with the whole or with any two or more of the rest, are estimated to be capable of producing upwards of sixteen thousand different movements—not reckoning as changes the various degrees of force and velocity, with which they are occasionally brought into action. These muscles, too, are only the proper muscles of the larynx, or the muscles restricted in their attachments to itsfive cartilages. They are but a few of the muscles of voice. In speaking, we use a great many more. Fifteen pairs of different muscles, attached to the cartilages, or to the os hyoides, and acting as agents, antagonists, or directors, are constantly employed in keeping the cartilages steady, in regulating their situation, and moving them as occasion requires—upwards and downwards, backwards and forwards, and in every intermediate direction, according to the course of the muscular fibres, or in the diagonal between different fibres. These muscles, independently of the former, are susceptible of upwards of 1073,841,800 different combinations; and, when they co-operate with the seven pairs of the larynx, of 17592186,044,415; exclusive of the changes, which must arise from the different degrees of force, velocity, &c. with which they may be brought into action.

But these muscles are not the whole that co-operate with the larynx, in the production of the voice. The diaphragm, the abdominal muscles, the intercostals, and all, that directly or indirectly act on the air, or on the parts to which the muscles of the glottis or os hyoides are attached,—in short, all the muscles that receive nerves from the respiratory system of Sir Charles Bell,—contribute their share. The numerical estimate would, consequently, require to be largely augmented. Such calculations are, of course, only approximate, but they show the inconceivable variety of movement of which the vocal apparatus is directly or indirectly susceptible.

The tone of the voice has been the great stumbling block to the physiologist and natural philosopher. The mode, in which it is produced, and the parts, more immediately concerned in the functions, have been the object of the various theories or hypotheses, from time to time enunciated regarding the voice.

Galen, under his theory, that the larynx is a wind instrument of the flute kind, of which the glottis is the beak and the trachea the body of the flute, ascribed the variety of tones to two causes—to variation in the length of the musical instrument and in the embouchure. Now, the trachea is susceptible of change in its length, when the larynx rises or descends, and the aperture of the glottis, we have seen, admits of a change in size, according to the action of its proper muscles. Accordingly, Galen ascribed the acute tone to the contraction of the embouchure—the glottis—and to the descent or depression of the larynx, which shortened the body of the instrument—the trachea; whilst the grave tone, he thought, was owing to the greater dilatation of the glottis, and to the larynx rising and elongating the trachea, and, consequently, lengthening the instrument.

The first part of the theory of Galen is correct. The glottis does contract for the production of acute tones; but, instead of descending in the case of acute tones, and rising in that of grave, the reverse is the fact; and, accordingly, what Galen calls the musical tube, in man, is elongated in the formation of acute tones, and shortened in the case of grave, which, every flute-player knows, is not the case in the artificial instrument.

This objection to the theory of Galen was obviated by that of Fabricius, of Acquapendente, who regarded the vocal tube or the whole of the space above the glottis as corresponding to the body of the flute; and, as the larynx ascends at the time of the production of acute sounds, and descends during that of grave, the length of the vocal tube or of the body of the instrument will be diminished in the former case and augmented in the latter, as in the artificial instrument.

In the theory of Dodart, to which allusion has been made, the human vocal instrument was likened to a horn; the inferior ligaments of the glottis being compared to the lips of the performer. He attached no importance to variation in the length of the instrument, but attributed the variety of tones to simple alteration in the *embouchure* or mouthpiece; in other words, to changes in the size of the glottis, by the action of its appropriate muscles.

The rising and falling of the larynx, he regarded as serving no other purpose than that of influencing, mechanically, the size of the aperture of the glottis.

Upwards of thirty years after this, Ferrein promulgated his belief, that the larynx is a stringed instrument; and he accounted for the variety of tones by the different degrees of tension and length of the inferior ligaments of the glottis or of the *vocal cords.* In the production of acute tones, these chords were stretched and shortened. For grave tones, they were relaxed, and, consequently, longer. He was of opinion, that the length of the vocal tube had no influence on the tone. Ferrein supported his theory by experiments, performed before commissioners appointed by the *Académie des Sciences.* These experiments consisted in forcing air from the trachea into the larynx of the human subject, as well as of animals, so as to produce vocal sounds, and to vary these by giving the vocal cords different degrees of tension. From these experiments he drew the conclusion, that he had succeeded in producing vocal sounds, which could be recognized—that, at the time of the production of this artificial voice he had distinctly seen the vocal cords vibrating; and that the different tones had been produced, not by a change in the aperture of the glottis, but by a variation in the tension and length of the vocal cords; and, according as one-half, two-thirds, or four-fifths of each chord was made to vibrate, the octave above, the fifth, or the third, or of the fundamental note was obtained. The result was the same, whether the two chords vibrated or only one; and if both cords were compressed in their whole length, so that they could not vibrate, no sound was produced.

To this theory, however, it was judiciously objected, that the "vocal cords" are not sufficiently dry, tense, or insulated, to execute vibrations, similar to those of musical cords; that, in many animals, possessed of voice, they are not apparent; and that, in birds, the tones of whose voices are various, they are replaced by cartilages, which can merely approach or recede from each other so as to modify the aperture of the glottis, but cannot be conceived susceptible of different degrees of tension; and, lastly, that these cords cannot, at the farthest, be shortened more than three lines, which would not be sufficient for the production of all the different tones of the human voice. It was farther asked—what use Ferrein assigned, in his theory, to the arytenoid muscle, and how he explained why the larynx rises or descends at each change of tone?

It would appear, likewise, that the academicians, who were present at his experiments, did not unanimously accord with Ferrein as to the results. Several of them asserted, that the sounds produced were rather a simple rustling of the air than real vocal sounds; and that, in the production of the sounds, the vocal cords acted like the reed.

Of late years, several new views have been propounded on this subject, and chiefly by Cuvier, Dutrochet, Magendie, Biot, Savart, &c.—men of the highest eminence in various departments of physical science.

Cuvier attributes the variety of tones, in the first place, to the varied length of the vocal tube, and to differences in the size of the aperture of the glottis; and, secondly, to the shape and condition of the external aperture of the tube—that is, of the lips and nose. The larynx he regards as a wind instrument, in which the inferior ligaments act, not as cords, but like the reed of a clarionet, or the *lame* of an organ pipe. The lungs and their external muscular apparatus constitute the reservoir of air and the bellows; the trachea conducts this air, and the glottis is the embouchure with its reed; the mouth and the whole of the space, comprised between the glottis and the opening of the lips, being the body of the instrument; whilst the openings of the nostrils are lateral holes, which permit the size of the instrument to be varied.

The tones are changed by three causes, of a similar character to those that modify them in musical instruments;—the length of the body of the instrument, the variableness of the embouchure, and of the aperture at the lower extremity of the instrument.

The condition of the external aperture of the vocal tube has, doubtless, much to do with the character of the tone produced by the glottis; but its influence appears to be greatly limited to giving it rotundity, volume, or the contrary, as will be seen hereafter; although analogy would seem to show, that the tone may be varied by more or less closure of the aperture. Many different notes can be produced in the first joint of a flute, if we modify the size of the opening at its extremity by passing the thumb more or less within it. It is doubtful, however, whether in man the altered size of the external aperture or the elongation or decurtation of the tube exerts as much influence on the production of acute or grave sounds as Cuvier imagines.

Dutrochet, again, believes, that the vocal tube has no influence in the production of tones, and that the larynx is a simple vibrating instrument, uncomplicated with a tube, the vocal sound being caused by the vibrations into which the vocal cords are thrown, by the impulse of the expired air. Dutrochet repeated the experiments of Ferrein, but without obtaining the same results. He was unable, for instance, to produce grave tones; those, which he succeeded in eliciting, comprised only one octave: even in the case of such of these as were the most acute, the inferior ligaments of the glottis were so tense, that the strongest rush of air could scarcely throw them into vibration, and the arytenoid cartilages were carried back much beyond the point to which the posterior crico-arytenoid muscles naturally draw them; he pronounces the remark of Ferrein—that the most acute sound was produced at the moment of greatest dilatation of the glottis—to be incorrect.

In these experiments, Dutrochet saw the inferior ligaments vibrate; and he concludes, that the tone of the voice depends upon the number of vibrations of these ligaments in a given time, and that the number will necessarily vary considerably, as the dimensions of the ligaments,—that is, their length, and thickness,—and their elasticity are susceptible of incessant changes, by the contraction of the thyro-arytenoid muscle of which they are essentially composed,—the ligament, covering the muscle, serving only "to prevent the collisions of the muscle at the time of vibration,"—as well as by that of the other intrinsic muscles of the larynx.

MM. Biot and Magendie dissent from Dutrochet in some important points. Like him, they do not consider the human larynx to constitute a stringed instrument. They regard it as a variety of reed instrument, but they consider the vocal tube to be of moment in the production of the voice. The objections they urge, against the view of its resembling the stringed instrument, are,—not only the kind of articulation between the arytenoid and cricoid cartilages, which admits of motion inward and outwards only, but they ask how the vocal cords can attain the length they would require for the production of grave tones; and how these cords could elicit sounds of a volume so considerable as those of the human voice. They esteem it, consequently, as a reed instrument—of such nature as to be capable of affording very grave tones with a pipe of little length; and such that the same tube, almost without varying its length, is susceptible, not only of furnishing a certain series of sounds in harmonic progression, but all the imaginable sounds and shades of sounds, in the compass of the musical scale, which each voice embraces.

In the reed instrument, comprising the clarionet, hautboy, bassoon, &c. two parts are distinguished,—the *reed*, and the *tube* or body. A reed is generally formed of one, sometimes of two, thin laminæ, capable of moving rapidly, and the vibrations of which alternately intercept and permit the passage of a current of air. In this instrument, the reed alone produces and modifies the sound. If the lamina be long, the movements are extensive, slow, and, consequently, give rise to grave sounds; a short lamina, on the contrary, produces acute sounds, because the movements are less extensive and more rapid. To vary the tones, it is, therefore, only necessary to vary the length of the reed. It is proper, however, to add, that the tone, according to Biot, is partly also dependent upon the elasticity, weight, and shape of the tongue or lamina, and on the intensity of the current of air; for if these elements vary,—the length continuing the same,—the tone changes. In a reed instrument, the reed is never employed alone. It is always adapted to a tube, through which the wind passes after it has thrown the reed into vibration. The tube, however, has no influence upon the tone of the sound. It affects only its intensity and *timbre*, and the practicability of making the reed speak. Those, that occasion the shrillest sounds, are such as are conical, with the expanded base outwards. If the cone be inverted, the sound becomes dull; but if two similar cones are applied, base to base, and adjusted to a conical tube, the sound assumes rotundity and force, an effect, which has not been accounted for by the natural philosopher.

A column of air, vibrating in a tube, can only produce a certain number of sounds; and, consequently, the tube of a reed instrument, when long, transmits only those sounds readily, which it is apt to produce; hence it generally becomes necessary to establish, beforehand, an accordance between the reed and the body of the instrument; and, when we are desirous of obtaining different sounds in succession from the same reed instrument, we have not only to modify the length of the reed, but, in a corresponding manner, that of the tube; and this is the use of the holes in the sides of the clarionet, bassoon, &c. By closing or opening these, the tube is placed in the proper relation with the reed. This accordance has the additional advantage of facilitating the production of any desired note from the reed, by means of the lips. The influence of the tube is very evident in the narrow instruments, as the clarionet and hautboy, in which it is extremely difficult to make the reed speak, unless the tube be previously adapted to its tone.

This theory of the reed instrument MM. Biot and Magendie apply to the human vocal apparatus. The lips of the glottis are the reed and the thyro-arytenoid muscles render them fit for vibrating.

In his experiments, made on living dogs, Magendie saw, that when grave sounds were produced, the ligaments of the glottis vibrated in their whole extent, and the expired air issued through the whole of the glottis. In acute sound, on the other hand, they vibrated only at their posterior part, and the air passed out through the part only that vibrated, the aperture being, consequently, diminished; and, when the sounds became very acute, the ligaments vibrated only at their arytenoid extremity, and scarcely any air issued; so that tones beyond a certain degree of acuteness, cannot be produced in consequence of the complete closure of the glottis. The arytenoid muscle, whose chief use is to close the glottis by its posterior extremity, he conceives to be the principal agent in the production of acute sounds, and this idea was confirmed by the section of the two laryngeal nerves, that give motion to this muscle, which was followed by the loss of the power producing almost all the acute tones; the voice, at the same time, acquiring a degree of habitual graveness, which it did not previously possess. The influence of contraction of the thyro-arytenoid muscles on the tones, he considers, are exerted in increasing or diminishing the elasticity of the ligaments, and, thus, in modifying the rapidity of the vibrations, so as to favour the production of acute or grave tones. He thinks, too, that the contraction of these muscles concurs greatly in closing, in part, the glottis, particularly its anterior half; although the course of its fibres, it appears to us, ought rather to widen the aperture.

The trachea or *porte-vent* has usually been considered to exert no influence on the nature of the sound produced. It has been conceived, however, by Grenié and others, that its elongation or decurtation may occasion some modification.

So much for the reed:—MM. Biot, and Magendie however include, in their theory of the voice, the action of the vocal tube, likewise. This tube, being capable of elongation and decurtation, of being dilated or contracted, and susceptible of assuming an infinite number of shapes, they think it well adapted for fulfilling the functions of the body of a reed instrument,—that is, if placed in harmonic relation with the larynx,—and thus of favouring the production of the numerous tones of which the voice is capable; of augmenting the intensity of the vocal sound by assuming a conical shape with a wide external aperture; of giving rotundity and sweetness by the proper arrangement of its external outlet, or by entirely subduing it, by the closure of the outlet. The larynx rises in the production of acute sounds; and falls in that of grave. The vocal tube is, consequently, shortened in the former case; elongated in the latter. It experiences also a simultaneous change in its width. When the larynx descends,—in other words, when the vocal tube is elongated, the thyroid cartilage is depressed and separated from the os hyoides by the whole height of the thyro-hyoid membrane. By this separation, the epiglottic gland is carried forwards, and lodged in the concavity at the posterior surface of the os hyoides. The gland drags after it the epiglottis; and a considerable enlargement in width occurs at the inferior part of the vocal tube. The opposite effect results, when the larynx rises. The use of the ventricles of the larynx, Magendie considers to be, to isolate the inferior ligaments, so that they may vibrate freely in the air. Lastly, in this theory the epiglottis has a use assigned to it which is novel. In certain experiments, instituted by Grenié for the improvement of reed instruments—being desirous of increasing the intensity of a sound without changing the reed in any respect, he found, that to succeed in it he was compelled to augment gradually the strength of the current of air; but this augmentation, by rendering the sounds stronger, made them rise. To remedy this inconvenience, Grenié found no means answer, except that of placing obliquely in the tube, immediately below the reed, a supple, elastic tongue, nearly as we see the epiglottis above the glottis. From this, Magendie infers, that the epiglottis may assist in giving to man the faculty of increasing or inflating the vocal sound, without its mounting.

Such are the main propositions of the theory of the voice by Biot, and Magendie. The larynx represents a reed with a double tongue; the tones of which are acute, in proportion to the decurtation of the laminæ; and grave in proportion to their length. They admit, however, that, although the analogy between the organ of voice and the reed is just, the identity is not complete. The ordinary reeds are composed of rectangular laminæ; fixed at one side, but loose on the three others; whilst, in the larynx, the vibrating laminæ, which are likewise nearly rectangular, are fixed by three sides and free by one only. Moreover, the tones of the ordinary reed can be made to rise or to descend by varying its length, whilst in the laminæ of the larynx the width varies. Lastly, say they, in musical instruments reeds are never employed, whose movable laminæ can vary in thickness and elasticity every moment, as is the case with the ligaments of the glottis; so that, although we may conceive, that the larynx can produce the voice and vary its tones, in the manner of a reed instrument, we are unable to demonstrate the particulars of its mode of action.

All the more modern theories—which we have detailed at more or less length—agree, then, in considering the larynx to be a wind instrument and of the reed kind: they differ, chiefly, in the part, which they assign to the vocal tube in causing the variation of tones.

More recently, in 1825, M. Savart has propounded a theory of the human voice, in which he differs from Cuvier, Dutrochet and Magendie;—denying, that the mechanism of the voice resembles that of the reed instrument, and returning to the old idea, which referred the vocal organs to an instrument of the flute kind.

The objections, which he makes to the doctrine, that likens it to a reed instrument, are the following.

In order that a reed shall produce a sound, it must be almost in contact with the sides of the gutter or depression in which it moves; so that the current of air may take place only periodically; but, according to this principle, the larynx would be unable to render any sound, whenever the inferior vocal ligaments are separated from each other.

Again, according to the theory of the reed, great efforts ought to be required to produce vocal sounds; for the thyro-arytenoid muscles being very strong and thick, it would seem, that they could not vibrate without a strong impulse; yet the voice is produced by the most feeble jet of air, and even when the breath is partly withheld.

Again, there is nothing in the sound of the voice, which resembles that of a reed, even of the best formation; and, lastly—he remarks—in the theory of the reed, no use is assigned to the ventricles of the larynx, and to the two superior ligaments of the glottis; which, with the epiglottis, form a membranous tube situated above the glottis; and yet it cannot be doubted, that these parts are important in the production of the voice; for, if we blow through the trachea into the larynx of a dead body, from which all but the inferior ligaments have been removed, vocal sounds can only be elicited by great exertion, whilst they can be easily produced in a perfect larynx,—even although the thyro-arytenoid muscles may not be contracted,—by merely approximating the arytenoid cartilages.

These objections led Savart to discard the doctrine, that the larynx is a reed instrument. The sounds of the human voice have, indeed, he remarks, a peculiar character, which no musical instrument can imitate; and this must necessarily be the case, as they are produced by a mechanism founded on principles, which do not serve as a basis for any of our instruments. He conceives, that the production of the voice is analogous to that of the sound in the tube of a flute, and that the small column of air, contained in the larynx and mouth, by the nature of the elastic parietes which bound them, as well as by the mode in which it is thrown into vibrations, is susceptible of rendering sounds of a particular nature, and at the same time, of a much more grave character than the dimensions would seem to admit.

In the tube of a flute the column of air, within, is the sonorous body. A sound is first produced at the *embouchure* of the instrument, by the division, which the air experiences when blown into it; and this sound excites similar sonorous undulations in the column of air, which fills the tube. The sound, resulting in this way, is more grave in proportion to the length of the tube; and it is in order to vary its tones, that the instrument has apertures in its side, by means of which the length may be modified.

In assimilating the human vocal apparatus to a flute, the great difficulty has been to explain how, with so short a tube as the vocal tube in man, and one so little variable in length, tones so different, and especially so grave, can be produced.

To explain this, Savart establishes the existence of a number of physical facts, previously unknown or unnoticed.

In organ pipes of great length the velocity of the current of air, which acts as a motor, has but little influence on the number of oscillations. When the length of the pipe is, for instance, twelve or fifteen times greater than its diameter, it is difficult to vary the sound a semitone. When the air is forcibly driven in, it rises an octave; and, when the velocity is diminished, the sound merely becomes more feeble; but is depressed an almost imperceptible quantity. In short pipes, on the contrary, the influence of the velocity of the current of air is much greater, and several tones can be elicited.

The bird-call, used by sportsmen, is illustrative of this principle. It is a small instrument, used for imitating the notes of certain birds; consisting of a cylindrical tube, about three-fourths of an inch in diameter, and a third of an inch high; closed at each end by a thin, flat plate, which is pierced, at its centre, by a hole about the sixth of an inch in diameter. Sometimes, it has the shape represented in the lower of the marginal figures. By placing this instrument between the teeth and lips, and forcing air, with more or less strength, through the two apertures, different sounds can be produced. This is more certainly effected, by attaching a porte-vent to the whistle, as A A, Fig. 90, when it is capable of producing all the sounds comprised in an extent of from an octave and a half to two octaves. M. Savart found, that, other things being equal, the diameter of the apertures has an appreciable influence on the acuteness or graveness of the sounds, which are more grave when the orifices are larger. The nature of the parietes of the instrument appeared, also, to exert some effect on the number of oscillations, and on the quality of the sounds; and if, in the hemispherical whistle, Fig. 90, the plain plate was replaced by a thin leaf of some extensible substance, as parchment, the sounds issued more readily, and were, usually, more grave, full, and agreeable, than when they were formed of a more solid substance.

Fig. 89.

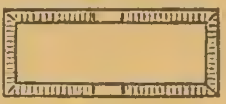
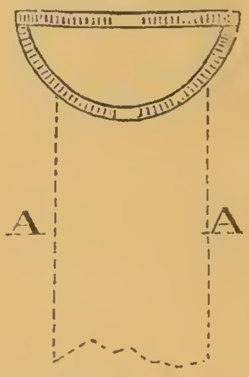


Fig. 90.



It is an opinion, generally admitted, that the material, which composes an organ pipe, has no influence on the number of vibrations, which the column of air, contained in it, is capable of executing. This is true as regards long pipes; but, according to Savart, it is not so with the short, and the nature of the *biseau** he conceives, may have a great influence, even on the sound of long pipes. For instance, if we substitute, for the stiff lamina, which forms the *biseau* of an organ pipe two feet long and two inches on the side, a lamina,

* The *biseau* or *languette* is the diaphragm, placed between the body of an organ pipe and its foot.

formed of some elastic substance, as skin or parchment, and so arranged as to admit of being stretched at pleasure; by gradually increasing the tension of the membrane, at the same time that we increase the velocity of the current of air, the tone may be made to vary a fourth, and even a fifth. In still shorter tubes, the much greater influence of the velocity of the current of air being united to that of the tension of the *biseau*, the result is still more evident. Thus, the sound of a cubical tube may easily be lowered an octave, when the parietes of the *biseau* are susceptible of different degrees of tension; but when all the parietes, which compose a short pipe, are of a nature to enter into vibration along with the air they contain, and when their degree of tension can be, moreover, varied, they have such an influence on the number of vibrations, that the sound it seems may be depressed indefinitely.

Short tubes, open at both extremities, and formed of elastic parietes, are also susceptible of producing a great number of sounds, even when they are only partly membranous.

The quality of the sound of membranous tubes is said to be somewhat peculiar. It partakes of that of the flute, and of the free reed.

Again, in order that a mass of air shall enter into vibration, a sound must be produced in some part of it. In an organ pipe, for example, a sound is first excited at the embouchure, and this throws the column of air, within the instrument, into vibration. Every sound, indeed, produced at the orifice of a column of air, throws it into vibration, provided its dimensions are adapted to the length of the waves produced directly;—hence, the utility of a musical pipe having parietes susceptible of varying in dimension and in tension, whatever may be the character of its *embouchure*.

Lastly.—The fundamental note of a tube, closed at one end, and whose diameter is every where the same, is an octave lower than the sound of the same tube, when open at both extremities. But this is not the case with tubes, that are of unequal diameter, conical, pyramidal, &c., when made to vibrate at their narrowest part. The tone, produced in such case, will increase in graveness, according to the difference between its narrow and expanded portions.

These different physical conditions Savart invokes to account for the different tones of the human voice,—under the theory, that the vocal organ—composed of the larynx, pharynx, and mouth—forms a conical tube, in which the air is set in vibration by a movement similar to that which prevails in organ pipes.

The trachea is terminated above by a cleft—the glottis—which is the inferior aperture of the vocal instrument. This cleft, which is capable of being rendered more or less narrow, plays the same part as the *lumière des tuyaux à bouche*, or the narrow space in the organ pipe, at the edge of the *biseau* or *languette*, along which the air passes. The air clears it, traverses the ventricles of the larynx, or the cavity of the instrument, and strikes the superior ligaments. These surround the upper aperture of the instrument, and fulfil the same function as the *biseau* of the organ pipe. The air, contained in the interior of the larynx, now vibrates, and sound is produced. This sound acquires intensity, because the waves, that constitute it, are extended into the vocal tube situated above the larynx, and excite, in the column of air filling it, a movement similar to that occasioned in the tube of a flute; except, that the tone can be much varied, because the larynx, being a short tube, can give rise to various tones by simple modification in the velocity of the air sent through it; and, moreover, the vocal tube has the same power, its parietes being membranous, of a vibratory nature, and capable of different degrees of tension. The inferior or outer part of the vocal tube is equally constituted of elastic parietes, susceptible of varied tension; and the mouth, by modifying the dimensions of the column of air within the vocal tube, exerts an influence on the number of vibrations which the column is capable of experiencing; whilst the lips can convert the channel at pleasure into an open or closed conical tube. Certain sounds, Savart affirms, are produced altogether in the ventricles of the larynx—those of pain and the *falsetto* voice, for example. They can be elicited, even when the vocal tube has been removed; and there are animals, in which the vocal organ is reduced to the ventricles of the larynx—frogs for instance. Savart, consequently, considers, that the human vocal organ has, in its essential parts, C C, B B, Fig. 88, a striking analogy to the action of the bird-call; and, in this way, he explains the use of the superior ligaments C C, which are entirely overlooked in the different theories of the voice previously propounded.

We have given Savart's view at some length, in consequence of its ingenuity, and of its seeming to explain better than any other theory the varied tones of which the human voice is susceptible. It cannot, however, be esteemed established, inasmuch as it is diametrically opposed, in many of its points, to the observations and vivisections of other distinguished physiologists; who, it has been seen, affirm, that voice is produced solely by the inferior ligaments; that all the parts above these may be destroyed, and yet voice may continue; and that a wound in the ventricles, which permits the exit of air through the parietes of the larynx, does not destroy the function. Our notions on this point must not, therefore, be considered definite. Farther experiments are necessary; and, in all deductions from them, great importance will have to be attached to the vital action of the organs, especially of the intrinsic muscles, which are capable of modifying the situation of parts, and the character of the function, in myriads of inappreciable ways.

Timbre, or Quality of the Voice.

In the preliminary essay on sound, attached to the physiology of audition, it was remarked, that the cause of the different timbres of sound, in the various musical instruments, had hitherto remained unexplained. The same remark is applicable to the timbre of the voice. Each individual has his own, by which he is distinguished from those around him; and it is the same with each sex and period of life. In this, the larynx is, doubtless, concerned; but in what manner is not clear. The feminine timbre or stamp, which characterizes the voice of the child and of the eunuch, would appear to be generally connected with the cartilaginous condition of the larynx; whilst the masculine voice, which is sometimes met with in the female, is connected with the osseous condition of these parts, and especially of the thyroid cartilage. An infinity of modifications may also be produced by changes in the thickness, elasticity, and size of the lips of the glottis.

The vocal tube probably exerts great influence in this respect, by its shape as well as by the nature of the material composing it. Such conditions, at least, appear to modify the timbre of our wind instruments. The timbre of a flute, made of glass or brass, is very different from that of one formed of wood, although the instruments may resemble each other in every other respect.

The form of the body of the instrument has, also, considerable effect. If it be conical, and wider towards its outlet, as in the clarionet, or hautboy, the quality of the sound is shrill. If it be entirely cylindrical, as in the flute, we have the soft quality, which characterizes that instrument; and on the other hand, if the tube be expanded at its middle portion, the quality of the sound is raucous and dull. It is probable, therefore, that we must reckon, amongst the elements of the varying character of the timbre or stamp of the voice, the different conditions of the vocal tube, as to length, width, and form; and that we must likewise include the position and shape of the tongue, of the velum palati, and of the mouth and nose, the presence or want of teeth, &c. all of which circumstances modify the voice considerably. The first modification takes place, probably, in the ventricles of the larynx, in which the voice requires more rotundity and expansion.

By the generality of physiologists, it is conceived, that the voice enters the different nasal fossæ, and, by resounding in them, a timbre or character is given to it, which it would not otherwise possess. According to this belief, when the voice is prevented from passing through the nose, from any cause, it acquires the *nasal* twang; or, by a singular inaccuracy of language, we are said "to talk through the nose." Magendie, however, considers, that, whenever the sound passes through the nasal fossæ, the vocal sound becomes disagreeable and nasal. Simple experiment, by holding the nose, exhibits, that, in the enunciation of the true vocal sound, unmodified by the action of the organs of articulation, the timbre or quality is materially altered; and we shall see, hereafter, that there are certain letters, which do not admit of enunciation, unless the nasal fossæ be pervious—the *m* and the *n*, and the *ng*, for example. It would seem that, under ordinary circumstances, the sound, after it is produced in the larynx, flows out by both channels; and that, if we either shut off the passage through the nose altogether, or attempt to pass the sound more than usually through the nasal fossæ, the voice becomes *nasal.*

The fine, sharp voice prior to puberty is especially owing to the narrowness of the glottis, to the shortness of the ligaments, and, according to Malgaigne, to want of developement of the nasal cavities. At puberty the size of the opening of the larynx is doubled: the ligaments enlarge, and the meatuses of the nose are augmented. The timbre now becomes raucous, dull and coarse, and for a time its harmony is lost. M. Bennati, himself an excellent theoretical and practical musician, whose voice marks three octaves, advises, that the voice should not be much exerted during this revolution. He has known perseverance in singing at this time completely destroy the voice in several instances.

Not only does the voice, when produced in the larynx, pass out by the vocal tube, but it resounds along the tracheal and bronchial tubes, giving rise to the resonance or thrill, which is audible in certain parts of the chest more especially, when the ear or the stethoscope is placed over them; and, when cavities exist in the lungs, in persons labouring under pulmonary consumption, if the ear be placed upon the chest, immediately over one of those cavities, the voice will appear to come directly up to the ear. The same thing happens, if the stethoscope be used. In this case, the voice will appear to pass directly through the tube to the ear, when the extremity of the instrument is applied over the vomica, so as to give rise to what Laennec terms *pectoriloquy.* Adelon conceives, that this distribution of the sound, along the trachea or *porte-vent* and the lungs, may induce a belief, that the condition of these organs has some effect on the timbre of the voice.

In speaking of the timbre of the voice in different individuals, we have had in view the natural quality, not that which is the result of imitative action, and which can be maintained for a time only. Many of the conditions, which have been described, as regulating the timbre, are voluntary, especially that of the shape of the vocal tube. In this way, we can modify the timbre and imitate voices very different from our own. The *table d'hote* of many of the hotels of continental Europe is enlivened by the presence of individuals, capable of not only imitating various kinds of birds, but the timbres of different musical instruments; and the success which has attended the personation of the different voices of public speakers, by Matthews, Yates, and others, is sufficient evidence of the fidelity of their representations.

We see the difference between the natural and imitative voice strongly exemplified in one of the feathered songsters of our forests, the *turdus polyglottis* or *mocking bird*, which is capable of imitating, not only the voices of other birds, but sounds of other character, which cannot be regarded in the light of accomplishments.

There is a singular variety of the imitative voice, now employed only for purposes of amusement—but, of old, perhaps, used in the Pagan temples, by the priests, to infuse confidence in the oracular dicta of the gods—which requires some notice; it is *engastrimism* or *ventriloquism.* Both these terms, by their derivation, indicate the views, at one time entertained, of its physiology, namely, that the voice of the ventriloquist is made to resound in the abdomen, in some inexplicable manner, so as to give rise to the peculiarity it exhibits. This singular view seems to have been once embraced by M. Richerand. "At first," says he, "I had conjectured, that a great part of the air expelled by expiration did not pass out by the mouth and nostrils, but was swallowed and carried into the stomach; and, being reflected in some part of the digestive canal, gave rise to a real echo; but, having afterwards more attentively observed this curious phenomenon on Mr. Fitzjames, who exhibits it in its greatest perfection, I was soon convinced, that the name of ventriloquism is by no means applicable."—M. Richerand was probably the last remnant of the ancient vague hypothesis, and his views soon underwent a conversion.

Another, equally unfounded notion, at one time entertained, was, that the ventriloquist possesses a double or triple larynx. It is now universally admitted, that the voice is produced at the ordinary place, and that it is modified in its intensity and quality by actions of the larynx and of the vocal tube, so as to give rise to the deceptions we experience.

It is known, that our appreciation of the distance and nature of a sonorous body is formed from the intensity and quality of the sound proceeding from it. We instinctively believe, that a loud sound proceeds from a near object, and a feeble sound from one more remote; accordingly, if the intensity and quality of the sound, from a known body, be such as to impress us with the idea, that it is more remote than it really is, we incur an acoustic illusion. The ventriloquist takes advantage of this source of illusion; and, by skilfully regulating the force and timbre of his voice, irresistibly leads us into error. Mr. Dugald Stewart gives some striking examples of this kind of illusion. He mentions having seen a person, who, by counterfeiting the actions of a performer on the violin, whilst he imitated the music by his voice, riveted the eyes of the audience on the instrument, although every sound they heard proceeded from his own mouth. Mr. Savile Carey, who imitated the whistling of the wind through a narrow chink, told Mr. Stewart, that he had frequently practised the deception in the corner of a coffee-house, and that he seldom failed to see some of the company rise to examine the tightness of the windows, whilst others, more intent on the newspapers, contented themselves with putting on their hats, and buttoning their coats.

It is to account for the mode in which this is effected, that different hypotheses have been, from time to time, entertained. Haller, Nollet, Mayer, and others, believed, that the voice is formed during inspiration; but this does not seem to be the case. Voice can certainly be effected during inspiration; but it is raucous, unequal, and of trifling extent only. Dumas and Lauth consider ventriloquism to be a kind of rumination of sounds; the voice, formed in the larynx, being sent into the interior of the chest, attaining there a peculiar timbre, and issuing of a dull character. Richerand is of opinion, that the whole mechanism consists in a slow, gradual expiration, which is always preceded by a deep inspiration. By means of this, the ventriloquist introduces into his lungs a considerable quantity of air, the exit of which he carefully regulates.

In the *Manchester Memoirs* Mr. Gough attempts to explain the whole phenomenon upon the principle of echoes;—the ventriloquist, he conceives, selecting a room, well disposed for echoes in various parts of it, and producing false voices, by directing his natural voice in a straight line towards such echoing parts, instead of in a straight line towards the audience, who are supposed, by Mr. Gough, to be placed designedly by the ventriloquist on one or both sides of him. A sufficient answer to this is, that the practised ventriloquist is careless about the room, chosen for his exhibitions; and that he habitually performs in rooms, where this system of echoes would be totally impracticable.

But let us see what the ventriloquists themselves have said of the mechanism of their art.

We pass over the explanation of Baron von Mengen, an Austrian colonel, who forms a kind of vocal organ between his tongue and his left cheek, if we understand his description correctly, and keeps a reservoir of air in his throat to throw this organ into vibration. His object must evidently have been to mislead.

In 1811, M. Lespagnol, a young physician, maintained a thesis on this subject before the *Faculté de Médecine* of Paris, which may be regarded, as at least, an honest exposition of his belief, regarding the mode in which the phenomenon was effected in his own person.

According to him, the whole is dependent upon the action of the velum pendulum palati. In the ordinary voice, he remarks, a part of the sound passes directly through the mouth, whilst another resounds in the nasal fossæ. If we are near the person who is speaking, these two sounds strike equally and almost synchronously upon the ear; but if we are at a distance, we hear only the first of the two sounds, when the voice appears more feeble, and, especially, has another timbre, which experience makes us judge to be that of the voice at a distance. The difference, says Lespagnol, between the voice that proceeds from a near, and that from a more distant object is, that in the former we hear the mixture of the two sounds; whilst in the latter we hear that sound only, which issues directly from the mouth. Now, the secret of the ventriloquist is, to permit this direct sound only to pass to the ear, to prevent the nasal sound from being produced, or at least from being heard; and this is done by the elevation of the velum pendulum palati; the vocal sound does not then resound in the nasal fossæ; the direct sound is alone produced; the voice has the feebleness and timbre that belong to the distant voice, and is judged to proceed from a distance; and if, during the performance, the voice seems to come from any determinate place, it is owing to the ventriloquist attracting our attention to it; the voice itself need only appear to proceed from a distance; and this it does more or less, according as the pendulous veil has more or less completely prevented the vocal sound from issuing by the nasal fossæ. The ventriloquist, thus, according to M. Lespagnol, makes the voice nearer or more remote at pleasure, by raising or depressing the velum palati. He denies that he speaks with his mouth closed; and affirms, that he articulates, but to a trifling extent only.

M. Comte, another ventriloquist, and of some celebrity, who has endeavoured to explain the physiology of his art, affirms, that the voice takes place as usual in the larynx; but that it is modified by the action of other parts of the apparatus; inspiration directing it into the thorax, where it resounds; and that both strength and flexibility are required in the organ to produce this effect. This, however, is no explanation. It is now universally admitted, that the voice of the ventriloquist is produced in the larynx; and that its character and intensity are modified by the action of other parts of the apparatus, but the particular action that produces it is not elucidated by any of these attempted explanations of the ventriloquist.

About twenty years ago, Dr. John Mason Good, in some lectures delivered before the Surrey Institution of London, suggested that the larynx alone, by long and dexterous practice, and, perhaps, by a peculiar modification in some of its muscles or cartilages, may be capable of answering the purpose, and of supplying the place of the associate organs of the mouth. In confirmation of this view, he remarks, that, in singing, the glottis is the only organ made use of, except where the notes are articulated; and it is apparently the sole organ employed in the mock articulations of the parrot and other imitative birds; some of which have exhibited unusual powers of articulation. A parrot, belonging to a Colonel O'Kelly, could repeat twenty of the most popular English songs, and sing them to their proper tunes.

The larynx, too, is the sole organ of all the natural cries; and hence, it has been imagined, by Lord Monboddo, to have been the chief organ of articulate language in its rudest and most barbarous state. "As all natural cries," he observes, "even though modulated by music, are from the throat and larynx, or knot of the throat, with little or no operation of the organs of the mouth, it is natural to suppose, that the first languages were, for the greater part, spoken from the throat; and that what consonants were used to vary the cries, were mostly gutterals; and that the organs of the mouth would at first be but very little employed." Certain it is, that the privation of tongue does not necessarily induce incapacity of articulation; whether the defect be congenital, or caused after speech has been acquired. Under the sense of taste, several authentic cases were stated of individuals, who were deprived of this organ, who yet possessed the faculty of speech. To these we may add one other, which excited unusual interest at the time, and was examined under circumstances, that could admit of no deception. The case forms the subject of various papers, by Dr. Parsons, in the *Philosophical Transactions*, between 1742 and 1747.

A young woman, of the name of Margaret Cutting, of Wickham market, near Ipswich, in Suffolk, when only four years old, lost the whole of her tongue, together with the uvula, from a cancerous affection; but still retained the powers of speech, taste, and deglutition, without any imperfection; articulating as fluently and correctly as other persons; and even those syllables that commonly require the aid of the tip of the tongue for accurate enunciation. She also sang admirably; articulating her words whilst singing; and could form no conception of the use of a tongue in other people. Her teeth were few, and rose scarcely higher than the surface of the gums, owing to the injury to the sockets from the disease that had destroyed the tongue. The case, when first laid before the Royal Society, was attested by the minister of the parish; by a medical practitioner of repute, and by another respectable individual. The society, however, were not satisfied, and they appointed commissioners to inquire into the case, whose report coincided minutely with the first; and, to set the matter completely at rest, the young woman was shortly afterwards conveyed to London, and examined, in person, before the Royal Society.

These cases are not so extraordinary as they appear at first sight to be; when we consider, that the tongue is not the sole organ of articulation, but that it shares the function with the various parts that compose the vocal tube. In reality, out of the twenty-four articulate sounds, which our common alphabet comprises, there are but few in which the tongue takes a distinct lead, as in the *l*, *d*, *t*, *r*, &c., though it is auxiliary to several others; but the guttural or palatine, *g*, *h*, *k*, *q*; the nasal, as *m* and *n*; the labial, as *b*, *p*, *f*, *v*; and most of the dental, together with all the vowels, are but little indebted to its assistance.

From these, and other concurrent facts, Dr. Good concludes, that ventriloquism appears to be an imitative art, founded on a close attention to the almost infinite variety of tones, articulations, and inflexions, which the glottis is capable of producing in its own region alone, when long and dexterously practised upon; and in a skilful modification of these vocal sounds, thus limited to the glottis, into mimic speech, passed, for the most part, and whenever necessary, through the cavity of the nostrils, instead of through the mouth. It is possible, he adds, though no opportunity has hitherto occurred of proving the fact by dissection, that those who learn this art with facility, and carry it to perfection, possess some peculiarity in the structure of the glottis, and particularly in respect to its muscles or cartilages. Magendie and Rullier, however, affirm, that the quiescence of the lips, observed in the practised ventriloquist when enunciating, is more apparent than real; and that, if he is capable of pronouncing without moving his lips, it is because he is careful to make use of words in which there are no labial consonants, or which do not absolutely require the movement of the lips in their formation. Rullier, indeed, denies positively, that the ventriloquist can speak without opening his mouth and moving his lips; but he affirms, that he uses his jaws, mouth, and lips, as little as possible in articulation; and he ascribes the common belief in their perfect quiescence to the habit, acquired by the ventriloquist, of restraining their movements, united to the care he takes in concealing them; and of giving to his face an impassive expression; or one very foreign to the verbal expression to which he is giving utterance.

On the whole, the explanation of Dr. Good appears most satisfactory:—the larynx or glottis affording to some individuals a facility in acquiring the art, which others do not possess, in the same manner as it makes some capable of singing, whilst others are ever incapacitated. It is probable, however, that there may be a greater degree of obscure action about the parts composing the vocal tube, than Dr. Good is disposed to admit; and that this may be materially concerned in giving the voice its peculiar quality and intensity; and in eliciting some of the sounds which might not be so easily produced by the action of the glottis alone. Sir David Brewster observes that when the ventriloquist utters sounds from the larynx without moving the muscles of his face, he gives them strength by a powerful action of the abdominal muscles: and Bennati affirms that the ventriloquist uses chiefly the pharyngeal voice, of which mention will be made under the head of *Singing*.

Such is the history of the simple voice, as effected in the larynx. Articulate sounds may, however, be produced in the vocal tube alone. *Whistling*, for example, is caused by the expired air being broken or divided by the lips; which act the part of the lips of the larynx in the production of voice.

Whispering consists in the articulation of the air of expiration. It is wholly accomplished in the vocal tube; and, hence, the impracticability of singing in a whisper; singing being produced in the glottis.

The sound of *sighing* is produced by the rushing of the air along the air passages, and especially along the vocal tube. In *laughing*, *crying*, and *yawning*, the voice is likewise concerned; but the physiology of these functions of expression will fall more appropriately under the head of respiration.

Having described the different views, that have been entertained, with regard to the production of voice, we shall now inquire into the function in connexion with expression. It this respect it admits of division into the *natural* or *inarticulate voice*, and into the *artificial* or *articulate*.

Of Natural or Inarticulate Language.

This, which is sometimes termed the *cry* or *native* voice, is an inappreciable sound, entirely produced in the larynx, requiring few or none of the organs of articulation to aid in its formation. As, however, it is caused by different degrees of contraction of the intrinsic muscles of the larynx, it is susceptible of a thousand different tones. It is elicited independently of all experience or education; seems to be inseparably allied to organization; and, consequently, occurs in the new-born infant, in the idiot, in the deaf from birth, and in the wild man, if any such there be, as well as in the civilized individual.

The natural voice differs as much as the sentiments it is employed to express. Each moral affection has its appropriate cry;—the cry of joy is very distinct from that of grief;—of surprise from that of fear, &c.; and the pathologist finds, in the diseases of children more especially, that he can occasionally judge of the seat of a disease by the character of the cry, to which the little sufferer gives utterance; in other words, that there is, in the language of Broussais, a cry peculiar to the suffering organ.

By the cry, our vivid sensations are expressed, whether they are of the external or internal kind; or are agreeable or painful; and, by it we exhibit all our natural passions, and most simple instinctive desires.

Generally, the most intense sounds to which the organ of voice can give utterance, are embraced in the natural cry: and, in its character, there is frequently something, which annoys the ear and produces more or less effect on those within its sphere. It is, indeed, by its agency, that sympathetic relations are established between man and his fellows; and between animals of the same kind.

The language, possessed by the greater part of animals, is, as we have already remarked, this natural voice, differing according to varying organization, and, therefore, instinctive; hence the various notes of birds; and the different ranges, which we find the voice to possess in the different species. Yet each species has one, by which it is distinguished, and which it possesses, even when brought up in the same cage with one of another species; or hatched, and attended to, by a foster mother, endowed with very different vocal powers. In the case of a goldfinch and chaffinch, this has been put directly to the proof; and it is well known, that the cuckoo, which is never hatched or nurtured by its own parent, still retains the note, which has acquired it its name in almost every language of the globe. It is, probably, by this natural cry, and not from any signs addressed to the eye, that the process of pairing is effected, and that the female is induced to select her mate.

The vocabulary of the common cock and hen is quoted as perhaps the most extensive of that of any tribe of birds, with which we are acquainted: or rather as Dr. Good remarks, we are better acquainted with the extent of its range than with that of any other. The cock has his watch-word for announcing the morning; his love-speech and his terms of defiance. The voice of the hen, when leaving her nest, after laying, is far different from that which she assumes, when the brood is hatched, and both are very different from her cries, when her young are placed in jeopardy. Even the chick exhibits a variety in its voice, according to the precise emotion it experiences.

All these sounds are such as the larynx of the animal permits alone to be produced: and hence we can understand why, so far, they should be mere modifications of the natural voice; but it is more than probable, that the chick learns the adoption of a particular sound by the parent, to express a particular emotion, as an affair of education. It can scarcely, indeed, be conceived, that the clucking of the hen, when she meets with food proper for her offspring, can be understood at first by the chick. But as soon as it traces the connexion between the sound produced and the object of such sound, it comprehends the signification ever afterwards.

There are sounds, which, from their discordant and harsh character, affect most animals perhaps, independently of all experience. The cry of terror or of pain appears to occasion, sympathetically, disagreeable effects in all that are within its sphere.

Of Artificial or Articulate Language.

Speech is, likewise, a vocal sound; but it is articulated, in its passage through the vocal tube; and is always employed to convey ideas, which have been attached to it by the mind. It is a succession of articulate sounds, duly regulated by volition, and having determinate significations attached to them.

The faculty of speech has been assigned, by some philosophers, chiefly to the organ of hearing. It is manifest, however, that this, like the musical ear, is referable to a higher organ. The brain must attach an idea to the impression, made upon it by the sound that impinges upon the organ of hearing; the sound, thus, becomes the *sign* of such idea, and is reproduced in the larynx, at the will of the individual.

Of the intellectual character of the process, we have the most decisive evidence. The infant, of tender age, has the ear and the voice well developed, yet it is long before he is capable of speech; and this does not happen until he discovers the meaning of the sounds addressed to him, and finds his own larynx capable of producing similar sounds, which can be made subservient to his wishes. It is thus, by imitation, that he acquires the faculty of speech. Again, the idiot, notwithstanding his hearing may be acute, and his voice strong, is incapable of speech; whilst, in the maniacal and delirious, the language participates in the derangement and irregularity of the ideas. The brain must, therefore, be regarded as the organ of the faculty of language, and the ear, larynx, and vocal tube as its instruments. Man, who is endowed with the most commanding intellect, has the vocal apparatus most happily organized for expressing its various combinations; and, according to Gall, if the ourang-outang and other animals are incapable of speech, it is because they have not the intellectual faculty of language. In proof that it is not to the vocal organ that this deficiency must be ascribed, he remarks, that animals may be made to enunciate several of the words of human speech, and to repeat them to music. The case of the far-famed parrot of Colonel O'Kelly has already been referred to; and Gall, amongst other cases, cites that of the dog mentioned by Leibnitz, which could articulate some German and French words. This dog, of which Leibnitz was "an eye-witness," was at Zeitz, in Misnia. A young child had heard it utter some sounds, which he thought resembled German, and this led him to teach it to speak. At the end of about eight years, it had learned thirty words, some of which were, *tea*, *coffee*, *chocolate*, *assembly*. It spoke only after its master had pronounced the word, and appeared to do so only on compulsion, although it was not ill used. In the "Dumfries Journal," Scotland, for January, 1829, mention is made of a dog, then living in that city, which could utter, distinctly, the word "William," the name of the young man to whom it was much attached. There is no doubt, however, that, in numerous animals, speech would be impracticable, owing to defective vocal organization, even were they gifted with adequate intellect.

It is difficult—perhaps impossible—to say, how man came to select certain sounds as the types of certain intellectual acts; nor is it a matter, which strictly concerns the physiologist. We may remark, however, that whilst some contend, that speech is a science which was determined upon, and inculcated, at an early period of the world, by one or more superior persons, acting in concert, and inducing those around them to adopt their articulate and arbitrary sounds; others affirm, that it has grown progressively out of the natural language, as the increasing knowledge and increasing wants of mankind have demanded a more extensive vocabulary.

The first view is that of Pythagoras and Plato; but it was opposed by Lucretius, and the Epicureans, on the ground, that it must have been impossible for any one person or synod of persons to invent the most difficult and abstruse of all human sciences, with the paucity of ideas, and of the means of communicating them, which they must have possessed; and that even allowing they could have invented such a science, it must still have been utterly impossible for them to teach it to the barbarians around them.

The opinions of those philosophers, who confine themselves to the phenomena of nature, and hold themselves uncontrolled by other authority, accord with those of the Epicureans.

In the origin of language, it is probable, that words were suggested to mankind by the sounds, which were heard around them: —by the cries of quadrupeds;—the notes of the birds of the forest; —the noises emitted by the insect tribe;—the audible indications from the elements, &c. These, being various, probably first of all suggested discriminative names, deduced from the sounds heard. It is this imitation of the noise, made by objects, that constitutes the figure of speech, called *onomatopœia*,—the "*vox repercussa naturæ*," or "echo of nature," as Wachter has defined it.

Daily experience shows us, that this source of words is strictly physiological. Children always designate a sonorous object by an imitation of the sounds given off by it; and the greater number of sonorous bodies have had names, radically similar, given to them in languages differing most from each other. We say the serpents "*hiss*," the bees "*hum*," the storm "*blusters*," the wind "*whistles*," the hogs "*grunt*," the hen "*cackles*," the man "*snores*," &c., words used, originally, not perhaps in these very shapes, but varying, according to the varying idiom of the language, to imitate the sounds elicited from these objects.

Such words are numerous in all languages, and have been adopted to depict both the sound emitted, and the sonorous body itself; but, in some cases, the word, imitating the sound, has survived its transmission from language to language to the most modern times, whilst the name of the object, whence it proceeded, has experienced considerable mutation.

The Sanskrit, the antiquity of which will not be contested, has a number of such words as *wilala*, the cat—*kukada*, the *hen*—and *waihu*, the wind; in the last of which the sound of the *w*, (*oo*,) imitates that of the passage of the air, and is found in the word corresponding to *wind*, (*ooind*,) in many languages. The Hebrew and the Greek have numerous phonetic words, but no language is richer, in this respect, than the Teutonic, in all its ramifications, including the English.

The animal kingdom affords us many examples, of which the following is one.

Cuckoo.—This word is nearly the same in almost all languages. Greek, κοκκυξ; Latin, *cucullus*; Irish, *cuach*; Bask, *cucua*; Sclavonic, *kukulka*, *kukuscka*, &c.; Hungarian, *kukuk*; Hebrew, *cacatha*; Syriac, *coco*; Arabic, *cuchem*; Persiac, *kuku*; Koriak, *kaikuk*; Kamtschadale, *koakutschith*; Kurile, *kakkok*; Tartar, *kauk*; German, *kuckucks*, or *guckguck*; Dutch, *koekoek*; whence our words *cuckoo* and *cuckold*, and the Scottish, *gouckoo*, *gowk*, or *golk*; French, *cocu*, &c.

In the greater part of languages, words, expressive of the cries of animals, are accurate imitations. Of this, the following are a few examples.

Bleating of sheep.—Greek, *βληχαομαι*; Latin, *balare;* Italian, *belare;* Spanish, *belar;* French, *béler;* German, *blöken;* Dutch, *bleeten;* Saxon, *blætan*, &c.

Howling of wolves.—Greek, *ὀλολυζω*; Latin, *ululare;* German, *heulen;* Dutch, *huilen;* Spanish, *aullar;* French, *hurler*, &c. Hence the word *owl.*

Neighing of the horse.—Latin, *hinnire;* French, *hennir;* German, *wiehern;* Saxon, *hnægan*, &c.

Clocking, or *clucking* of hens.—Latin, *glocire;* French, *glousser;* Greek, *κακκαζειν*: German, *glucken;* Dutch, *klokken;* Saxon, *cloccan*, &c.

To *crow*, like a cock.—Greek, *κραζω*; German, *krähen;* Dutch, *kraayen;* Saxon, *craw*, &c. whence the word *crow*, the bird.

The Latin words *tinnimentum, tinnitus, tintinnabulum*, &c. from *tinnio*, I ring, are all from the radical *tin;* imitating the sound rendered on striking a metallic vessel. The *gurgling* of water, the *clanging* of arms, the *crash* of falling ruins, are of the same character; and the game *trictrac*, formerly *tictac*, seems to have been so called, from the noise made in putting down the men or dice.

In whatever manner language was first formed, it is manifest, that the different sounds could make but a transient impression, until they were reduced to legible characters, which could bring them back to the mind. On our continent, the fact has often been noticed of a tribe of Indians, separating themselves into two parties, and remaining distinct for years. In such cases, the language has become so much modified, that after the lapse of a considerable period they have scarcely been able to comprehend each other. Hence, the importance of the art of writing, certainly the most valuable of human inventions. Of this, there have been two kinds,—the *imitative* or *alphabetic*,—and the *symbolical, allegorical*, or *emblematic*, which latter consists of hieroglyphics, or designs representing external objects, or of symbolical allegories.

The former or the written representation of spoken sounds alone concerns us. To attain this, every compound sound has been reduced to certain elementary sounds, which are represented by signs, called *letters.* These elementary sounds, by combination, form *syllables;* and the syllables, by combination, *words.* The number of elementary sounds, admitted in each language, constitutes its *alphabet*, which differs more or less in certain languages; but as it is entirely a matter of human invention, and as the elementary sounds, of which the human voice is capable, are alike in the different races of mankind, we see readily, that the alphabets of the different languages must strikingly correspond, although the combinations of the letters constituting syllables and words, may vary essentially.

Into the origin of the written legible language, it is not necessary for us to inquire. We may remark, however, that the invention has been considered so signally wonderful as to transcend the human powers; and hence St. Cyril, Clement of Alexandria, Eusebius, Isidore, and, in more modern times, Messrs. Bryant, Costard, &c. have been of opinion, that the knowledge of letters was first communicated to Moses by the Almighty himself, and that the decalogue was the earliest specimen of alphabetic writing. Many passages, however, in the writings of Moses, show unequivocally, that written records must have existed prior to his time. In the passage in which writing is first mentioned in the sacred volume, the art is alluded to as one of standing:—"And the Lord said unto Moses, 'Write this for a memorial in a book or table;'" and in a subsequent chapter—"And thou shalt make a plate of pure gold, and grave upon it, like the engravings of a signet, Holiness to the Lord."

The English alphabet is considered to consist of twenty-six letters. It may, however, by ultimate analysis, be reduced to twenty-four simple sounds—A, B, D, E, F, G, H, I, J, K, L, M, N, O, P, R, S, T, U, V, Z, Ch, Sh, and Th. To these letters arbitrary names have been assigned, as *Bee* (B,) *See,* (C) *Dee,* (D,) &c. which express very different sounds from those that belong to the letter when it forms part of a word or syllable. The word *bad* is not pronounced *bee-a-dee;* as the child, just escaped from learning his alphabet, must imagine; hence, he has to unlearn all that he has acquired, or to imagine, that the different letters have very different sounds, according to the situation in which they may be placed. To obviate this inconvenience, many individuals are in the habit of teaching their children syllabically from the very first, by which they acquire the true sound, attached to each letter of the alphabet.

In the preceding enumeration of the simple sounds, which constitute the alphabet, C, Q, W, X, and Y, have been excluded, for the following reasons. C has always the sound of either S or K, as in *cistern* or *consonant.* Q has the sound of *koo,* as in quart, (*kooart;*) W of *oo,* as in word, (*oourd;*) X of *ks,* or Z, as in vex, (*vecks,*) or Xerxes, (*zerkses;*) whilst Y has the sound of I or E, as in wry or yard, (*wri* or *eeard.*) *Ch, Sh,* and *Th,* have been added, as being true alphabetic or simple sounds.

Letters have been usually divided into two classes,—*vowels* and *consonants.*

The *vowels* or *vocal sounds* are so called, because they appear to be simple modifications of the voice, formed in the larynx, uninterupted by the tongue and lips, and passing entirely through the mouth. Such at least is the case with those that are reckoned *pure vowels.* These, in the English alphabet, are five in number,—A, E, I, O, and U. W and Y are, likewise, vowel sounds in all situations,

In enunciating A, as in *fate,* the tongue is drawn backwards and slightly upwards, so as to contract the passage immediately above the larynx. In sounding E, the tongue and lips are in their most natural position, without exertion. I is formed by bringing the tongue nearly into contact with the bony palate. O, by the contraction of the mouth being greatest immediately under the uvula, the lips being also somewhat contracted. In the production of U, the contraction is prolonged beneath the whole of the soft palate.

From these principal vowels, all the other vowel sounds of the language may be formed, by considering them as partaking more or less of the nature of each. These are, in our language, thirteen in number; besides compound sounds, as in *oil* and *pound*. Of these thirteen, three belong to A; two to E; two to I; three to O; and three to U.

A, as in - -	Fate. Fat. Fall.	O, as in - -	No. Move. Not.
E, as in - -	Me. Met.	U, as in - -	Tune. Tub. Bull.
I, as in - -	Pine. Pin.		

The vowels are more easy of pronunciation than the consonants. They merely require the mouth to be opened; and, however it may be arranged in the enunciation of the different vowels, the vocal tube is simply modified, to vary the impression, which has to be made on the organ of hearing. The shape of the cavity is altered, but the passage of the air continues free, and the voice, consequently, issues in an unrestrained manner. Hence, perhaps, the physiological origin of the Danish word *Aa*, "a river"—a generic term, which became afterwards applied to three rivers in the Low Countries, three in Switzerland, and five in Westphalia—the sound of the two broad As flowing without obstacle, like a river. Time passes away in a similar manner; hence, for a like reason, the Greek αει which signifies "always, perpetually;" and the German j e, which has the same signification.

The consonants are more difficult of enunciation than the vowels; as they require different, and sometimes complex, and delicate movements of the vocal tube; and, on this account, are not acquired so early by children.

The term *consonant* is derived from one of its uses,—that of binding together the vowels, and being sounded with them; but it may be defined,—an interruption to the sound, effected in the larynx, by the application of the organs of articulation to each other.

By most, and according to Mr. Walker, by the best, grammarians, *w* and *y* are consonants, when they begin a word; and vowels when they end one. Dr. Lowth, however, a man of learning and judgment, who certainly would not suffer in a comparison with any of his opponents, regards them, as we have, to be always vowels. Physiologically it is impossible to look upon them in any other light. Yet Mr. Walker exclaims,—"how so accurate a grammarian as Dr. Lowth could pronounce so definitely on the nature of *y*, and insist on its being always a vowel, can only be accounted for by considering the small attention which is generally paid to this part of grammar." No stronger argument, however, could be used against the useless expenditure of time on this subject, than the conclusion to which Mr. Walker himself, has arrived; and for which he can find no stronger reasons, than that if *w*, and *y* have every property of a vowel, and not one of a consonant; why, when they begin a word, do they not admit of the euphonick article *an* before them?

The consonants are usually divided into *mutes*, *semi-vowels*, and *liquids*.

The *mutes* are such as emit no sound without a vowel; as *b*, *p*, *t*, *d*, *k*, and *c* and *g* hard.

The *semi-vowels* are such as emit a sound, without the concurrence of a vowel, as *f*, *v*, *s*, *z*, *x*, *g* soft or *j*.

The *liquids* are such as flow into, or unite easily with, the mutes, as *l*, *m*, *n*, *r*. These letters issue without much obstacle; and hence perhaps their name.

In tracing the mode in which the different consonants are articulated, we find, that certain of them are produced by an analogous action of the vocal tube; so that the physiology of one will suffice for the other also. For instance, the following nearly correspond;—

p	*f*	*t*	*s*	*k*	*ch*
&	&	&	&	&	&
b	*v*	*d*	*z*	*g*	*j*.

B and P are produced when the lips, previously closed, are suddenly opened. B differs from P in the absence, in the latter, of an accompanying vocal sound. F and V are formed by pressing the uper incisor teeth upon the lower lip. They are, consequently, not well enunciated by the aged, who have lost their teeth. F differs from V only in the absence of an accompanying vocal sound. T and D are formed by pressing the tip of the tongue against the gums behind the upper incisor teeth: D is accompanied by a vocal sound; T not. S and Z are produced by bringing the point of the tongue nearly in contact with the upper teeth, and forcing the air against the edges of the teeth with violence. S differs from Z in the absence of the vocal sound. K and G are formed by pressing the middle of the tongue against the roof of the mouth, near the throat; and separating the parts a little more rapidly to form the first, and more gently to form the last of those letters. In K, the accompanying vocal sound is absent. Ch and J are formed by pressing *t* to *sh*; and *d* to *zh*. In Ch, there is no accompanying vocal sound.

SH and ZH are formed in the same part of the tube as *s* and *z*.

TH is formed by protruding the tongue between the incisor teeth, and pressing it against the upper incisors to produce its sound in *think*. Its sound in *that*, is effected by pressing the tongue behind the upper incisor teeth. In the former case, it is unaccompanied by a vocal sound.

In M, the lips are closed, as in B and P, and the voice issues by the nose.

N is formed by resting the tongue against the gums, as in the enunciation of *t* and *d;* and breathing through the nose with the mouth open.

In L, the tip of the tongue is pressed against the palate, the sound escaping laterally.

In forming the letter K, the middle and point of the tongue strikes the palate with a vibratory motion; the tip being drawn back.

Lastly, in the formation of H, the breath is forced through the mouth, which is every where a little contracted. It need hardly be said, that the enunciation of these letters requires, that the vocal tube, or the parts concerned in the function, shall be in a sound condition.

Wolfgang von Kempelen in a work on the mechanism of human speech, &c. which is considered classical in Germany, divides the consonants into four classes. 1. *Mutes*, (ganz stumme,) as K, P, T. 2. *Explosives*, (windmitlauter,) as the F, H, Ch, S, and Sh. 3. *Vocal consonants*, (stimmitlauter,) as B, D, G, L, M, and N; and 4. *Vocal explosives*, (wind und stimmlauter,) as R, I, W, V, Z.

Dr. Thomas Young has, likewise, divided the English consonants into classes; of which he enumerates five. 1. *Pure semi-vowels*, as L, R, V, Z, and J. 2. *Nasal semi-vowels*, as M and N. 3. *Explosive letters*, as B, D, and G. 4. *Susurrant letters*, as H, F, X, and S: and, 5. *Mutes*, as P, T, K.

The most satisfactory classification, in a physiological, as well as philological point of view, is according to the parts of the vocal tube, more immediately concerned in their articulation.

Labial.	Dento-labial.	Linguo-dental.	Linguo-palatal.	Guttural.
B M P	F V	Th	D J L N R S T Z Ch Sh Ng	G K

That this physiological arrangement has had much to do with the formation of congenerous tongues more especially, is exhibited by the facts, connected with the permutation or change of letters; when a word passes, for example, from one of the Teutonic or Romanic languages to another.

"The changes of vowels," says Mr. Lhuyd, "whether by chance or affectation, are so very easy and so common in all languages, that in etymological observations, they need not, indeed, be much regarded; the consonants being the sinews of words, and their alterations therefore the most perceptible. The changes of consonants also into others of the same class, (especially *labials*, *palatals*, and *linguals*,) are such obvious mistakes, that there is no nation where the common people in one part or other of their country, do not fall into some of them."

A few examples will show to what extent this permutation occurs between letters of the same class in different languages. In this view, we may regard the labials and dento-labials as belonging to the same class.

P into B.—Greek, φλεψ; Latin, *phlebs*. Latin, (and Greek,) *episcopus;* English, *bishop;* Anglo-saxon, *biscop;* German, bischof.

P into F and V.—Latin, *pater;* German, vater; Dutch, *vader;* English, *father*.

T into S.—German, besser; English, *better*. German, wasser; English, *water*.

D into Th.—German, das; Dutch, *dat;* English, *that*.

T into Z.—German, zung; Dutch *tong;* English *tongue*. German, zweig; English *twig*.

L into R.—Spanish, *Gil Blas;* Portuguese, *Gil Bras*. Latin, *arbor;* Spanish, *albero*.

C or K into G.—Latin, *hemicranium;* French, *migraine*. Latin, *cibarium;* French, *gibier*. Latin, *acer;* Italian, *agro*. Latin, *alacer;* Italian, *allegro*. Greek, κυκνος; Latin, *cygnus*.

The most harmonious languages are such as have but few consonants, in their words, compared with the vowels; hence the musical superiority of the Greek and Italian, over the English, German, &c.

"Among certain northern nations," says Richerand, "all articulated sounds appear to issue from the nose or the throat, and make a disagreeable pronunciation, doubtless because it requires greater effort; and he who listens, sympathizes in the difficulty, which seems to be felt by him that speaks;" and he adds,—"would it not seem that the inhabitants of cold countries have been led to use consonants rather than vowels, because as the pronunciation does not require the same opening of the mouth, it does not afford the same space for the continual admission of cold air into the lungs?" The whole of Richerand's remarks on this topic are singularly fantastic and feeble, and unworthy of serious discussion.

In regard to the consonants, it has been presumed, that some common imitative principle must have existed with all nations, so as to cause them to conform in adopting such as produce a certain sound to convey the same effect to the ear.

Dr. John Wallis, in his *Grammatica Linguæ Anglicanæ*, published in the seventeenth century, turned his attention to this matter, chiefly as regards the English language, and he has collected a multitude of examples to show, that a certain collocation of consonants, at the commencement of a word, generally designates the class of ideas, intended to be conveyed by it. For instance, he remarks that:—

Str, always carries with it the idea of *great force* and *effort* :—as *strong, strike, stripe, strife, struggle, stretch, strain*, &c.

St, the idea of strength but in less degree—the *vis inertiæ*, as it were:—as *stand, stay, stop, stick, stutter, stammer, stumble, stalk, steady, still, stone*, &c.

Thr, the idea of violent motion:—as *throw, thrust, throb, threat, throng*, &c.

Wr, the idea of obliquity or distortion:—as *wry, wreathe, wrest, wring, wrestle, wrench, wriggle, wrangle, wrinkle*, &c.

Br, the idea of violent,—chiefly sonorous,—fracture or rupture: —as *break, brittle, brust* or *burst, brunt, bruise, broil*, &c.

Cr, the idea of straining or dislocation, chiefly sonorous:—as *crack, creak, crackle, cry, crow, crisp, crash*.

Other words, beginning with those consonants, communicate the idea of curvature, as if from *curvus*:—as *crook, cringe, crouch, creep, crawl, cripple, crumple, crotchet*, &c.

Others, again, denote decussation, as if from *crux*:—as *cross, cruise, crutch, crosier*.

Shr, the idea of forcible contraction:—as *shrink, shrivel, shrug, shrill*, &c.

Gr, the idea of the rough, hard, onerous and disagreeable, (either owing to the letter of roughness *r*, or from *gravis*,)—as *grate, grind, gripe, grapple, grieve, grunt, grave*, &c.

Sw, the idea of silent agitation or of gentle lateral motion:—as *sway, swag, swerve, sweat, swim, swing, swift*, &c.

Sm, a very similar idea to the last:—as *smooth, smile, smirk, small*, &c.

Cl, the idea of some adhesion or tenacity:—as *cleave, clay, cling, climb, cloy, cluster, close*, &c.

Sp, the idea of some dispersion or expansion, generally quick, (especially with the addition of the letter *r*,)—as *spread, spring, sprig, sprinkle, split, splinter, spill*, &c.

Sl, the idea of a gently gliding or slightly perceptible motion:—as *slide, slip, slippery, slime, sly, slow, sling*, &c.

Lastly, *Sq, Sk, Scr*, denote violent compression:—as *squeeze, squirt, squeak, squeal, skreek, screw*, &c.

Some other interesting observations on the collocation of consonants, at the termination, and in the body, of words, are contained in the grammar of Wallis. His remarks, however, are chiefly confined to his own tongue. M. De Brosses has taken a wider range, with a similar object, and endeavoured to discover, why certain consonants, or a certain arrangement of consonants in a word, should designate certain sensible properties, in all languages. Why, for instance, the *st* should enter into most words signifying firmness and stability:—as in the Sanskrit, *stabatu*, to stand, *stania*, a town, &c.; in the Greek, στηλη, a column, στερεος, solid, immovable, στειρα, sterile, remaining constantly without fruit, στηριζω, I fix firmly, &c.; in the Latin, *stare*, to stand, *stirps*, a stem, *stupere*, to be astonished, *stagnum*, stagnant water, &c. and he might have added in the German, still-stehend, stagnant, stadt, a town, stand, condition, sterben, to die, still-stand, cessation, &c., besides the English words, commencing with *st*, already quoted from Wallis.

He farther inquires, why words, commencing with *sc*, denote hollowness, as σκαπτω, I dig; σκαφη, a skiff or boat, in the Greek; *scutum*, a shield; *scyphus*, a large jug; *sculpere*, to engrave; *scrobs*, a ditch, in the Latin; *ecuelle*, formerly *escuelle*, a dish; *scarifier*, to scarify; *scabreux*, scabrous; *sculpture*, &c., in the French; and similar words might be added from our own language. *Ecrire*, formerly *escrire*, the French for "to write," is from the Latin *scribere*; and, anciently, a kind of style was used for tracing the letters in wax; which instrument, by a like analogy, was called, by the Greeks, σκαριφος.

M. de Brosses accounts for these, by supposing, that the teeth, being the most immovable of the organic apparatus of the voice, the firmest of, what he calls, the dental letters T has been mechanically employed to denote stability; and that, to denote hollowness, the K or C has been adopted,—which are produced in the throat, the most hollow of the vocal organs. The letter S serves, he conceives, merely as an augmentative; as the sound can, by its addition, be made continuous. It is itself, however, a letter expressive of softness, when combined, as we have seen, with certain other consonants; or when employed alone at the commencement of a word.

In the same manner, the letters *fl* are used to designate the motion of fluids more especially,—as in the Greek, φλοξ, flame; φλεψ, a vein; φλεγεθων, a burning river in the infernal regions:—in the Latin, *flamma*, flame; *fluo*, I flow; *flatus*, wind; *fluctus*, wave, &c.:—in the German, flössen, to float; flöten, to play on the flute; fluss, a river; flug, flight, &c.; and the French and English words of the same meaning.

Lastly, the idea of roughness and asperity is conveyed by the letter *r*, as in the words, *rude*, *rough*, *rock*, *romp*, &c. How different, for example, in smoothness are the two following lines, in which the S predominates; from those that succeed them, where the R frequently, and perhaps designedly, occurs.

> "Softly sweet in Lydian measures,
> Soon he sooth'd his soul to pleasures;"

And—

> "Now strike the golden lyre again,
> A louder yet, and yet a louder strain;
> Break his bands of sleep asunder;
> And rouse him like a rattling peal of thunder."

The remarks that have been made, suggested by those of Wallis and of M. de Brosses, must not be received too absolutely. In the condition in which we find languages at the present day, it would be impossible that they should hold good universally; but they will tend to show, that the physiology of the voice is intimately connected with this part of philology; and that the sounds emitted by the agency of particular parts of the vocal tube, may have led to the first employment of those sounds, according to the precise idea it may have been desired to convey;—gutturals, for example, for sounds conveying the notion of hollowness:—resisting dentals, that of obstacles, &c. The words *mama* and *papa* are composed of a vowel and consonant, which are the easiest of enunciation, and which the child, consequently, pronounces and unites earlier than any other. Hence they have become the infantile appellations for *mother* and *father* with many nations; but, it is scarcely necessary to say, the child, when it first pronounces the combinations, attaches no such meaning to them, as the parent fondly imagines.

Lastly, there is a rhetorical variety of the onomatopœia, frequently considered under the head of *alliteration*, but by no means deriving its chief beauties from that source. It happens when a repetition of the same letter concurs with the sonorous imitations already described; as in the following line in one of the books of the Æneid of Virgil:—

> "Luc*t*an*t*es ven*t*os *t*empes*t*a*t*esque sonoras,"

in which the frequent occurrence of the letter of firmness and stability, T, communicates the idea of the striking of the winds on objects.

In the "*Andromaque*" of Racine, a line of this character occurs:—

> "Pour qui sont ces serpens qui sifflent sur vos têtes,"*

in which the sound impressed on the ear has some similarity to the hissing of serpents: and in the "*Poëme des Jardins*" of the Abbé De Lille, there is the following example:—

> "Soit que sur *l*e *l*imon une rivière *l*ente,
> Dérou*l*e en paix les p*l*is de son onde indo*l*ente;
> Soit qu'a t*r*ave*r*s les *r*ocs un to*rr*ent en cou*rr*oux
> Se b*r*ise avec f*r*acas."†

In the first two lines the liquid L denotes the tranquil flow of the river; whilst in the two last, the letter of roughness and asperity, R, resembles the rushing of the stream like a torrent. The remarks already made will have exhibited the radical difference in the ideas

* "For whom are those serpents that hiss o'er your heads."

† Which may be translated as follows:—
> "If o'er a deep slime a river laves,
> In peace the folds of its sluggish waves;
> Or o'er the rocks a torrent breaks
> In wrath obstrep'rous."

communicated by the sound of those letters, by the common consent of languages.

In the German language, this variety of expression is often had recourse to; and by none more frequently than by their poet Bürger.

The English language affords a few specimens, but not as many as might be imagined. Of simple alliteration, there are many; some that give delight; others that do violence to the suggestive principle; but there are comparatively few, where the words are selected, which, by their sound, convey to the mind the idea to be communicated.

The galloping of horses may be assimilated by a frequent succession of short syllables; slow, laborious progression by the choice of long; but, in the onomatopœia in question, the words themselves must consist of such a collocation of one consonant, or of particular consonants, as adds force to the idea communicated by the words collectively. Of this, the following example may be cited, in which the repetition of the letter R, in the various phonetic words especially, adds considerable force to the idea intended to be conveyed by the passage.

> "Loud sounds the axe, redoubling strokes on strokes;
> On all sides round the forest hurls her oaks
> Headlong. Deep echoing groan the thickets brown,
> Then rustling, crackling, crashing, thunder down."

Of Singing.

The singing voice differs from the other sounds produced by the glottis, in consisting of appreciable sounds, the intervals of which can be distinguished by the ear, and which admit of unison.

Under the sense of hearing we endeavoured to show, that the musical ear is an intellectual faculty; and that the ear is only the instrument for attaining a knowledge of sounds, which are subsequently reproduced by the larynx, under the guidance of the intellect. In this respect, therefore, there is a striking resemblance between the faculty of music and that of spoken language.

Like the spoken language, singing admits of considerable difference, as regards intensity, timbre, &c.

Voices are sometimes divided into the *grave* and the *acute*; the difference between them amounting to about an octave. The former is the voice of the adult male; but it is capable of producing acute sounds, by assuming the *falsetto*, which Savart conceives to be produced in the ventricles of the larynx,—Bennati in the pharynx.

The acute voice is that of the grown female, of children, and of eunuchs.

By adding all the tones of an acute to those of a grave voice, they are found to embrace nearly three octaves; but, according to Magendie, it does not appear, that such a compass of voice, in pure and agreeable tones, has ever existed in the same individual. Some singers can descend sixteen tones below the medium: others can rise sixteen above it. The former are called *tenor bass;* the latter *soprano*, but hitherto no example has occurred of a person, who could run through the thirty-two notes.

The musician establishes certain distinctions in the voice; such as *counter, tenor, treble, bass,* &c. We find it, also, differing considerably in strength, sweetness, flexibility, &c.

The singing voice, according to Bennati, is not limited to the larynx; the pharynx is likewise concerned. The voice, elicited in these two different parts, has long been termed *voce di petto* and *voce di testa.* Bennati calls the former *laryngeal notes*, or *notes of the first register;* the latter *supra-laryngeal* or *notes of the second register:* and Lepelletier designates them *laryngeal* and *pharyngeal* respectively,—comprising in the dependencies of the pharynx, the tongue, the tonsils and the velum palati, by means of which the latter class of sounds is elicited. The *laryngeal voice*, which is always more elevated by an octave in the female than in the male, is most commonly met with. It furnishes the types called 1. *Alt* or *soprano;* 2. *Counteralt*, 3. *Tenor;* 4. *Tenor Bass.* The pharyngeal voice presents but modifications of these types. It is met with in but few persons in its finest developement. It has usually been supposed to be formed by the superior ligaments of the larynx or in the ventricles; but these gentlemen esteem it demonstrated, that it is formed at the guttural aperture, circumscribed by the base of the tongue, the velum palati, its pillars, and the tonsils. By it is produced the *baritenor*, the *contraltino tenor*, and the *soprano sfogato.* Bennati concludes his memoir on the human voice by remarking,—that not only are the muscles of the larynx inservient to the modulation of the notes of song; those of the os hyoides, tongue, and of the superior, anterior and posterior part of the vocal tube are invoked, without the simultaneous and properly associated operation of which, the degree of modulation requisite for song could not take place.

It has been already remarked, that the natural voice or cry is allied to the organization of the larynx. So far as it can be modified into tones independently of the participation of the intellect, a natural singing voice may be said to exist. To repeat, however, any song, requires both ear and intelligence: and, therefore, singing may be said to have originated in social life. It can be employed, as it is in many of our operas, to depict the different intellectual and moral conditions,

"And bid alternate passions fall and rise."

When the air is accompanied by the words, or is articulated, we are capable of expressing, by singing, any of the thoughts or feelings, that can be communicated by ordinary artificial language.

Declamation is a kind of singing, except that the intervals between the tones are not entirely harmonic, and the tones themselves not wholly appreciable. With the ancients, it has been imagined, declamation differed much less from singing than with the moderns, and that it probably resembled the *recitative* of the operas.*

OF THE GESTURES.

Under this appellation, and that of *muteosis*, are comprised all those functions of expression, which are addressed to the sight and the touch. It comprises not only the partial movements of the face, but also those of the upper extremities; besides the innumerable outward signs characterizing the various emotions. In many tribes of animals, the conventional language appears to be almost, if not entirely, confined to the gestures; and even in man—favoured, beyond all animals, in the facility of communicating his sentiments by the voice—the language of gestures is rich and comprehensive.

It is in the gestures of the face chiefly, that man far exceeds other animals. This is, indeed, in him, the great group of organs of expression. In animals, the function is distributed over different parts of the body, the face assuming but little expression whilst the animal is labouring under any emotion, if we make exception of the brute passion of anger and of one or two others. Hence it is, that, by some naturalists, man has been defined, by way of distinction, "a laughing and crying animal." In animals, almost all the facial expression of internal feeling is confined to the eye and the mouth, whilst the attitude of the body is variously modified, and the hair is raised by the panniculus carnosus—as we see on the back of the dog, when the animal is enraged.

In the human countenance, alone, in the state of society, can the passions be read, the rest of the body being covered by clothing; and even were it not, the absence of a coat of hair, and of a panniculus carnosus, would enable it to minister but little to expression. The skin of the face is very fine, and on certain parts, as the lips and cheeks, it is habitually more or less florid, and admits of considerable and expressive variations in its degree of colour. The union of the different parts, composing the face, gives occasion to numerous reliefs, which are called *traits* or *features;* and, beneath the skin, are many muscles, capable, by their contraction, of modifying the features in a thousand ways.

To comprehend fully the physiology of the facial expression of the passions, a few observations on the muscles of the human face will be necessary.

* The ingenious work of Dr. James Rush, of Philadelphia, on the *Philosophy of the Human Voice*, may be consulted, on this subject, with great advantage.

The *eyebrow* is a part greatly concerned in expression; and certain muscles are attached to it for the purpose of moving it.

The fasciculus of fibres, which descends from the *frontal muscle* A, Fig. 34, and is attached to the side of the nose, has been esteemed, by some, to be a distinct muscle, and to have a distinct operation. It draws the inner extremity of the eyebrow downwards. When the *orbicularis palpebrarum*, C C, and the last muscle act, there is a heavy lowering expression. If they yield to the action of the frontal muscle, the eyebrow is arched, and there is a cheerful, inquiring expression. If the corrugator supercilii acts, there is more or less of mental anguish, or of painful exercise of thought. If it combines with the frontalis, the forehead is furrowed, and there is an upward inflection of the inner extremity of the eyebrow, which indicates more of querulous and weak anxiety.

"The arched and polished forehead," says Sir Charles Bell—of whose elegant and accurate *Essays on the Anatomy and Philosophy of Expression* we shall occasionally avail ourselves on this branch of our subject—"terminated by the distinct line of the eyebrow, is a table, on which we may see written, in perishable characters, but distinct while they continue, the prevailing cast of thought; and by the indications here, often the mere animal activity displayed in the motions of the lower part of the face, has a meaning and a force given to it. Independent of the actions of the muscles, their mere fleshiness gives character to this part of the face. The brow of Hercules wants the elevation and form of intelligence; but there may be observed a fleshy fulness on the forehead, and around the eyes, which conveys an idea of dull brutal strength, with a lowering and gloomy expression, which accords with the description in the *Iliad*."

Sir Charles Bell separates the *orbicularis palpebrarum* into two muscles;—the outer, fleshy, circular band, which runs round the margin of the orbit; and the lesser band of pale fibres, which lies upon the eyelids. These last are employed in the act of closing the eyelids, but the former is only drawn into action in combination with the other muscles of the face in expressing passion, or in some convulsive excitement of the organ. In laughing and crying, the outer and more powerful muscle is in action, gathering up the skin about the eye, and forcing back the eyeball itself. In drunkenness, the power of volition over this muscle is diminished; and there is an attempt to raise the upper eyelid by a forcible elevation of the eyebrow.

The *muscles of the nostrils* are;—first, the *levator labii superioris alæque nasi*, D, Fig. 34, which, as its name imports, raises the upper lip and nostril; 2dly, the *compressor nasi*, E, a set of fibres, which compress the nostril; and 3dly, the *depressor alæ nasi*, L, which lies under the *orbicularis oris*, and whose function is indicated by its name.

These three muscles serve to expand and contract the opening or canal of the nostril; moving in consent with the muscles of respiration; and thus the inflation of the nostrils indicates general excitement, and animal activity.

The muscles of the lips are; 1, the *levator labii proprius*, F, which raises the upper lip; 2dly, the *levator anguli oris*, G, which raises the angle of the mouth; and 3dly, the *zygomatic muscle*, H, which is inserted into the angle of the mouth. Sometimes an additional muscle of the name exists;—*zygomaticus minor*.

These last muscles raise the upper lip and the angle of the mouth, so as to expose the canine teeth. If they be in action, contrary to the orbicularis oris, there is a painful and bitter expression; but if they are influenced along with the orbicularis oris, and orbicularis palpebrarum,—if the former of these muscles be relaxed, and the latter contracted,—there is a fulness of the upper part of the face, and a cheerful, smiling expression of countenance.

The *orbicularis oris*, K, closes the mouth; and, when allowed to act fully, it purses the lips. The *nasalis labii superioris*, M, draws down the septum of the nose. The *triangularis oris*, or *depressor labiorum*, N, indicates, by its name, its function. The *quadratus menti*, O, is a depressor of the lower lip. The *levatores menti*, P P, by their action, draw up the chin, and project the lower lip; and the *buccinator*, Q, is chiefly for turning the alimentary bolus in the mouth; and, in broad laughter, it retracts the lips.

The orbicularis muscle is affected in the various emotions of the mind; trembling and relaxing in both grief and joy. It relaxes pleasantly in smiling.

The union of these various muscles at the angle of the mouth produces the fleshy prominence, noticed in those who have thin faces; and who are, at the same time, muscular. When the cheeks are fat and full, the action of these muscles produces the dimpled cheek.

The angle of the mouth is full of expression, according as the orbicularis, or the superior, or inferior muscles, inserted into it, have the preponderance.

Lastly, the *temporal* is a strong muscle, which raises the lower jaw. It is assisted by the *masseter*, a deep-seated muscle, which lies on the outside of the lower jaw, arises from the jugum, and is inserted into the angle of the jaw.

Two different nerves are distributed to these muscles;—the fifth pair; and the portio dura or facial of the seventh. Whilst the first of these is a nerve of sensation, and also conveys to the muscles the volition, necessary for their ordinary movements of mastication, &c., the latter is concerned in the instinctive movements of expression. This the experiments of Sir Charles Bell have demonstrated; and comparative anatomy exhibits, that the number and intricacy of these nerves vary in proportion to the animal's power of expression.

The nerves of the face and neck of the monkey are numerous, and have frequent connexions; but, on cutting the seventh pair, or *respiratory nerve of the face* of Sir Charles Bell's system, the features are no longer influenced by the passions. Yet the skin continues sensible, and the muscles of the jaws and tongue are capable of the actions of chewing and swallowing. If the respiratory nerve of one side be cut, the expression of that side is destroyed; whilst the chattering, grinning, and other movements of expression continue in the other. In a dog, too, if the respiratory nerve of the face be cut, he will fight as bitterly, but with no retraction of his lips, sparkling of his eye, or drawing back of the ears. The face is inanimate, though the muscles of the face and jaws, so far as they are liable to influence through other nerves, continue their offices.

The game cock, in the position of fighting, spreads a ruff of feathers around his head. The position of his head and the raised feathers are the expressions of hostile excitement, but, on the division of the respiratory nerve, the feathers are no longer raised, although the pugnacious disposition continues.

It has been, moreover, found, that if the galvanic influence be passed from one divided extremity of the respiratory nerve to the other, the facial expression returns; and, in certain cases of incomplete hemiplegia, in which the expressive movements of the face were alone rendered impracticable, the disease was found to have implicated only the respiratory or facial nerve.

The views of Sir Charles Bell, regarding the connexion, alleged by him to subsist, between the seventh pair and the associated movements of respiration, have, however, been contradicted by the experiments of Fodéré and Mayo, and his inferences regarding the fifth pair—as being jointly a nerve of sensation and voluntary motion—have been considered by Mayo to require qualification. By dividing the portio dura of the seventh pair in the ass, and on both sides instead of one, as done by Sir Charles Bell, Mr. Mayo found, that the nerve presides over simple voluntary motion only: and by a similar division of the second and third branches of the fifth, at their points of convergence, he showed, that the lips were deprived of sensation not of motion. "No doubt, I believe," says Mr. Mayo, "is now entertained, that the inference, which I drew from these experiments, is correct;—namely, that the portio dura of the seventh pair is a simple voluntary nerve, and that the *facial branches* of the fifth are exclusively sentient nerves." In the prosecution of his inquiries Mr. Mayo observed, that the masseter muscle, the temporal, the pterygoids, and the circumflexus palati receive no branches from any nerve except the fifth, and yet that they receive twigs from the ganglionic portion of the nerve; and he thence concludes, that almost all the branches of the large or ganglionic portion of the fifth pair are nerves of sensation, whilst those of the small fasciculus or *ganglionless* portion are nerves of motion. This smaller portion of the fifth pair issues from the peduncles of the brain, constitutes a gangliform plexus with the inferior maxillary only, presents the common aspect of most nerves of the body, and is distributed to the chief muscles concerned in the process of mastication. Hence it was termed by Bellingeri, *nervus masticatorius*, and by Sir Charles Bell, long afterwards, the *motor* or *manducatory portion of the fifth nerve*. To this smaller fasciculus of the fifth, twigs from the ganglionic portion of the nerve, are distributed. The ganglionless portion, and the portio dura of the seventh, Mayo conceives to be voluntary nerves to parts, which receive sentient nerves from the larger or ganglionic portion of the fifth.

Pathology affords us numerous examples of injury done to the facial nerve. In some of these cases, the nerve itself may be in a morbid condition in some portion of its course: in others, the part of the encephalon, whence the nerve originates, may be the seat of the lesion. The prognosis will, of course, vary according to the seat, but as a general rule, paralysis of the facial nerve is not of great moment. Within the last two years, the author has seen three cases of partial paralysis of this kind; one of which has wholly disappeared; but in the others it appears to be permanent. In a case, which presented itself not long ago, in the Baltimore Infirmary, the mischief was probably seated near the origin of the nerve, as it resulted from serious injury to the head. A carriage horse, belonging to a friend, by exerting considerable power, forced its head through an aperture in the partition of his stall, and was unable to withdraw it, in consequence of the under-jaw catching the sides of the aperture. During the efforts to extract it, so much pressure was made upon the portio dura of one side, that the animal lost all power of expression in the corresponding side of the head: the soft parts about the mouth dropped, and the ear no longer associated with that of the opposite side in expression: yet the movements of mastication and deglutition were scarcely affected. This state of paralysis continued for a few days, and gradually disappeared.

Independently of the various muscular actions, which modify the expression of the human countenance, there are certain other indications which mark the different mental emotions. The skin, for example, varies in colour, becoming pale or suffused; and frequently alternating rapidly between these two conditions. These changes are more especially witnessed on the forehead, cheeks, and lips; and arise from an augmented or diminished flow of blood into the capillaries of the part, under the influence of the existing emotion. Under such circumstances the eye may participate in the suffusion: the skin may also vary in its degree of moisture or of heat. It may be dry, or bathed in perspiration; and the perspiration may be warm or cold;—occasionally the two conditions alternating frequently. Particular parts of the face, again, are more susceptible of this "sweat of expression," as it has been termed;—the forehead and temples, for example. The heat of the head is also occasionally modified; a sudden glow will be felt in the countenance; and the expression is sometimes evident to a second person.

The expression of the human eye, connected with the action of the oblique muscles, has been referred to under vision. It was there asserted, that, in insensibility, the eye is given up to the action of the oblique muscles, and is drawn up under the upper eyelid. The eye itself is, however, capable of various expressions, depending upon varied position of its tutamina; and especially of the secretion from its mucous covering—the conjunctiva—and from the lachrymal gland; so that the eye may be swimming, or the tears may flow over the cheeks and constitute *weeping*.

In addition to these, which may be regarded as sources of expression in the human countenance, we may add the action of *osculation* or *kissing*, which, wherever practised, is employed as an expression of love and friendship; confined with us to those of the female sex, or of opposite sexes; but, in some countries, employed as an expression of regard between males also.

It is impossible for us to describe all the facial expressions—the *Prosopose*, as they have been collectively termed—of which the human countenance is susceptible. They are commonly classed under two heads:—the *exhilarating*, in which the face is flushed, and the countenance expanded; the muscles being contracted from within to without; and the *depressing*, in which, on the contrary, the face is pale, and the features are drawn inwards and sunken.

Let us inquire into the physiology of a few of these expressions; beginning with the play of the features in broad *laughter*, as being, perhaps, the most easy of explanation. In laughing, it is in vain

Fig. 91.

Broad laughter.

that we endeavour to confine the lips; a complete relaxation of the orbicularis oris gives uncontrolled power to the opponent muscles inserted into the angles of the mouth and upper lip. Hence the lateral retraction of the angles of the mouth; the elevation of the upper lips disclosing the teeth; the peculiar elevation of the nostrils without their being expanded, and the dimple of the cheek, where the acting muscles congregate; and hence, also, the fulness of the cheeks, rising so as to conceal the eye, and throw wrinkles about the lower eyelids and the temples. In this expression, the whole of the movable features are raised upwards. The orbicularis palpebrarum does not partake of the relaxation of the orbicularis oris. It is excited, so as to contract the eyelids, and sink the eye, whilst the struggle of a voluntary effort of the muscles to open the eyelids, and raise the eyebrow, gives a twinkle to the eye, and a peculiar obliquity to the eyebrow; the outer part of which is most elevated.

In this movement of expression we have a striking instance of the associated action of the different parts of the respiratory system of nerves of Sir Charles Bell. The facial expression is under the direction of the portio dura or respiratory nerve of the face. At the

Fig. 92.

Faun weeping.

same time, the individual holds his sides to control the contractions of the muscles of the ribs. The diaphragm is violently agitated. The same influence spreads to the throat, and the sound of laughter is as distinct as the signs in the face.

In the face of a Faun, Fig. 92, sketched by Sir Charles Bell, we have the expression of *weeping* from pain.

In the violence of weeping, accompanied with lamentation and outcry, the face is flushed or suffused from the stagnation of blood in the vessels. The muscles of respiration are here affected from the commencement, and the return of the blood from the head is somewhat impeded. The muscles of the cheeks are in action. Those that depress the angles of the mouth are powerfully contracted, and the orbicularis oris is not relaxed, but drawn open by the predominant action of its opponents.

A convulsive action in the muscles about the eyes attends; the eyebrow is drawn down; the eyes are compressed by the eyelids; the cheek is raised; the nostril drawn out, and the mouth stretched laterally. In weeping, also, unless the convulsive action of the muscles be very strong, the expression of grief affects that part of the eyebrows which is next the nose. It is turned up with a peevish expression, which corresponds with the depression of the corners of the mouth.

This depression of the angle of the mouth gives an air of despondency and languor to the countenance, when accompanied by general relaxation of the muscles. When the corrugator co-operates, there is mingled in the expression something of mental energy, moroseness, or pain. If the frontal muscle unites its action, an acute turn upwards is given to the inner part of the eyebrow, very different from the effect of the general action of the frontal muscle, and characteristic of anguish, debilitating pain, or of discontent, according to the prevailing cast of the rest of the countenance.

The depression, however, of the angle of the mouth, that indicates languor and despondency, must be slight; as the depressor anguli oris, (Fig. 34, N.) cannot act forcibly, without the action of the superbus being induced,—a muscle, which quickly produces a revolution in the expression and makes the under lip pout contemptuously.

The expression at the angles of the mouth demands the careful study of the painter; the most opposite characters being communicated to the countenance by their elevation or depression. When Peter of Cortona was engaged on a picture of the iron age for the royal Palace of Pitti, Ferdinand II., who often visited him, and witnessed the progress of the piece, was particularly struck with the exact representation of a child in the act of crying. "Has your majesty," said the painter, "a mind to see how easy it is to make this very child laugh?" The king assented: and the artist, by merely elevating the corner of the lips and inner extremity of the eyebrows, made the child, which at first seemed breaking its heart with weeping, seem equally in danger of bursting its sides with immoderate laughter. After which, with the same ease, he restored the figure to its proper expression of sorrow.

It is at the angle of the mouth and the inner extremity of the eyebrow, that the expression, which is peculiarly human, is situated. They are the most movable parts of the face. In them the muscles are concentrated, and it is upon their changes, that expression is acknowledged chiefly to depend. All the parts, however, of an impassioned countenance have an accordance with each other. When the angles of the mouth are depressed in grief, the eyebrows are not elevated at the outer angles as in laughter. When a smile plays around the mouth, or when the cheek is elevated in laughter, the eyebrows are not ruffled as in grief. In real emotion, these opposite actions cannot be combined; and, when they are united by the mimic, the expression is farcical and ridiculous.

Dr. Wollaston has shown, that the same pair of eyes may appear to direct themselves either to or from the spectator, by the addition of other features in which the position of the face is changed. The nose is obviously the principal feature, which produces the change of direction, as it is more subject to change of perspective than any of the other features, and Dr. Wollaston has shown, that even a small portion of the nose will carry the eyes along with it. He obtained four exact copies of the same pair of eyes looking at the spectator, by transferring them upon copper from a steel plate, and having added to each of two pairs of them a nose—in one case directed to the right, and in the other to the left, and to each of the other two pairs a very small portion of the upper part of the nose—all the four pairs of eyes lost their front direction, and looked to the right or to the left, according to the direction of the nose, or of the portion of it which was added. But the effect, thus produced, is not limited to the mere change in the direction of the eyes: for a total difference of character may be given to the same eyes by a due representation of the other features. A lost look of devout abstraction, in an uplifted countenance, may be exchanged for an appearance of inquisitive archness in the leer of a younger face, turned downwards and obliquely towards the opposite side. This, however, as Sir David Brewster has remarked, is not perhaps an exact expression, of the fact. The new character which is said to be given to the eyes is given only to them in combination with the new features; or, what is probably more correct, the inquisitive archness is in the other features, and the eye does not belie it. Sir David adds, that Dr. Wollaston has not noticed the converse of these illusions, in which a change of direction is given to fixed features by a change in the direction of the eyes. This effect is seen in some magic lantern sliders, where a pair of eyes is made to move in the head of a figure, which invariably follows the motion of the eyeballs.

In *bodily pain*, the jaws are pressed together, and there is grinding of the teeth; the lips are drawn laterally, so as to expose the teeth and gums; the nostrils are distended to the utmost, and, at the same time, drawn up; the eyes are largely uncovered, and the eyebrows elevated; the face is turgid with blood, and the veins of the temple and forehead are distended; the breath being suspended, and the descent of the blood from the head impeded.

In *anguish*, conjoined with *bodily suffering*, the jaw falls; the tongue is seen; and, in place of the lateral retraction of the lips, the lower lip falls, the eyebrows are knit, whilst their inner extremities are elevated; the pupils of the eyes are in part concealed by the upper eyelids, and the nostrils are agitated. Agony of mind is here added to the bodily suffering, which is particularly indicated by the change in the eyebrow and forehead.

In *rage*, the features are unsteady: the eyeballs are largely seen, roll, and are inflamed. The forehead is alternately knit and raised in furrows, by the motion of the eyebrows; and the nostrils are inflated to the utmost; the lips are swelled, and, being drawn, open the corners of the mouth. The action of the muscles is strongly marked. The whole countenance is sometimes pale, and sometimes inflated, dark and almost livid; the words are passed forcibly through the fixed teeth, and the hair is on end.

Fear has different degrees. Mere *bodily fear* resembles the mean anticipation of pain. The eyeball is largely uncovered; the eyes are staring, and the eyebrows elevated to the utmost stretch. To these are added a spasmodic affection of the diaphragm and muscles of the chest, which affects the breathing, and produces a gasping in the throat, with an inflation of the nostril, convulsive opening of the mouth and dropping of the jaw;—the lips nearly concealing the teeth, yet allowing the tongue to be seen, and the space between the nostril and lip being full. There is a hollowness and convulsive motion of the cheeks, and a trembling of the lips and muscle on the sides of the neck. The lungs are kept distended; and the breathing is short and rapid. The surface is pale from the recession of the blood; and the hair is lifted up by the creeping of the skin.

In fear, where the apprehended danger is more remote, but is approaching, the person trembles and looks pale; a cold sweat is on his face; the scream of fear is heard; the eyes start forward; the lips are drawn wide; the hands are clenched, and the expression becomes more strictly animal, and indicative of such fear as is common to brutes.

In *terror*, or that kind of fear, in which the mind participates more, there is a more varying depression in the features, and an action of those muscles, that are peculiar to man, and which seem to indicate his superior intelligence and mental feeling. The eye is bewildered, the inner extremity of the eyebrows turned up and strongly knit, by the action of the corrugator and orbicular muscles; and distracting thoughts, anxiety and alarm are strongly indicated by this expression, which does not belong to animals. The cheek is slightly elevated, and all the muscles, that concentrate about the mouth, are in action.

In *admiration*, the forehead is expanded and unruffled; the eyebrow gently raised; the eyelid lifted so as to expose the coloured circle of the eye, whilst the lower part of the face is relaxed into a gentle smile. The mouth is open; the jaw a little fallen; and, by the relaxation of the lower lip, we just perceive the edge of the lower teeth and the tongue.

In *joy*, the eyebrow is raised moderately, but without any angularity; the forehead is smooth; the eye full, lively and sparkling; the nostril moderately inflated, and a smile is on the lips.

This subject is, however, interminable. Enough has been said to exhibit the anatomy of the varying characters of facial expression. It will be found beautifully treated and illustrated in the work of Sir Charles Bell to which reference has been made.

From all that has been said, it is evident, that the countenance is a good general index of the existing state of the feelings; but farther than this it cannot be depended upon. Yet, in all ages, it has been regarded as the index of individual character. Allusion has been made to the estimate of personal character, from the shape of the head, as described by the older poets. Similar indications were conceived to be deducible from the form of the face, the expression of the eyes, &c. Thus, Shakespeare:—

> *Cleopat.* Bear'st thou her face in mind? is't long or round?
> *Messeng.* Round, even to faultiness.
> *Cleopat.* For the most part too,
> They are foolish that are so. Her hair, what colour?
> *Messeng.* Brown, Madam, and her forehead
> As low as she would wish it."
>
> *Antony and Cleopatra*, Act III. Scene 3.

And again:—

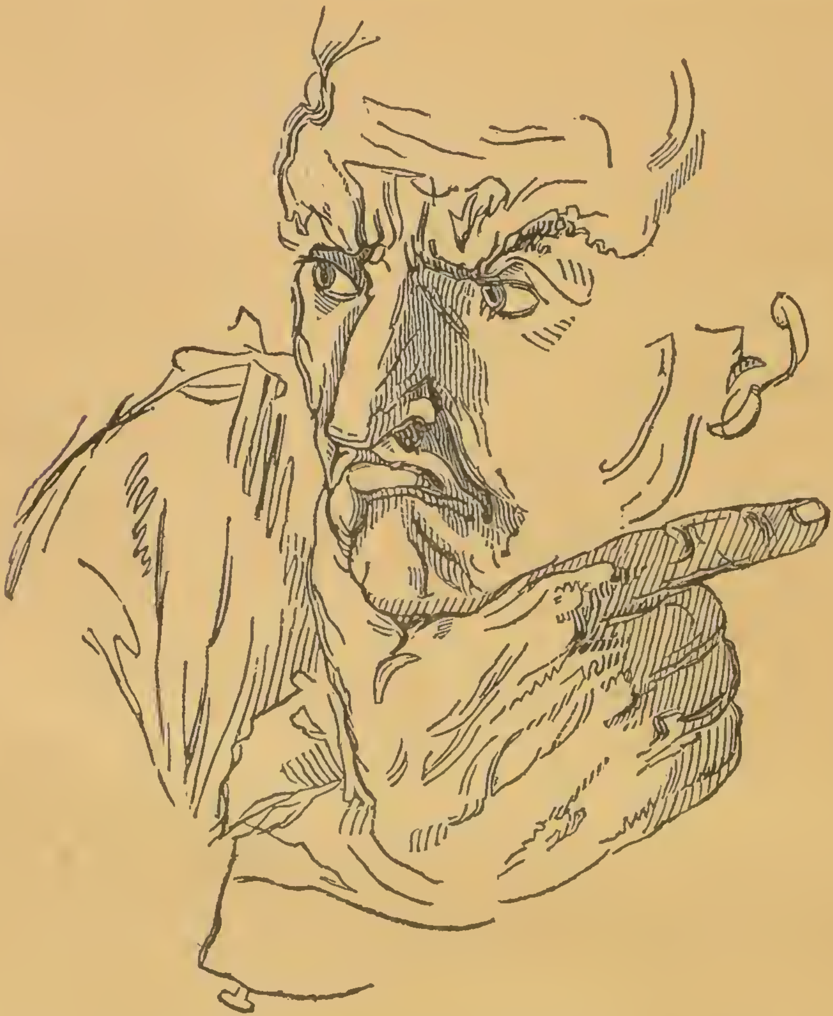
> "Which is the villain? Let me see his eyes,
> That when I note another man like him,
> I may avoid him."
>
> *Much Ado about Nothing.*

John Baptist Porta and Lavater have endeavoured to establish a science, by which we can be instructed, how to discover the secret dispositions of the head and the heart from the examination of particular features. The latter enthusiast, in particular, appears to have carried his notions to the most chimerical extent. "No study," he remarks, "excepting mathematics, more justly deserves to be termed a *science* than *physiognomy.* It is a department of physics including theology and belles lettres, and in the same manner with these sciences may be reduced to rule. It may acquire a fixed and appropriate character. It may be communicated and taught."

In another place, he remarks, that no person can make a good physiognomist unless he is a well-proportioned and handsome man; yet he himself was by no means highly favoured in these respects, and it is, consequently, difficult to say, according to his own theory, how he attained such progress in the "*science.*"

There is one case, and perhaps, one only, in which physiognomy can aid us in the appreciation of character. We have remarked, that the facial expression may accurately depict the existing emotion. If, therefore, any passion be frequently experienced, or become habitual, its character may remain impressed upon the countenance, and an opinion be formed of the individual accordingly. No one, who has seen the melancholy mad, can mistake the piteous expression produced by brooding over the corroding idea that engrosses him.

Fig. 93.



In the above sketch, from Sir Charles Bell, we have the testy, peevish countenance, bred of melancholy; of one who is incapable of receiving satisfaction from whatever source it may be offered, and who "cannot endure any man to look steadily upon him, or even to speak to him, or laugh, or jest, or be familiar, or hem, or point, without thinking himself contemned, insulted, or neglected." Such a countenance no one can misapprehend.

In lesser degrees, particular features are found bearing, or seeming to bear, the impress of particular emotions; and, accordingly, we are in the daily habit of forming opinions at first sight, both of the intellectual and moral characteristics of individuals, by the expression of the countenance. Of course, we are frequently led into error; inasmuch as the habitual feelings alone are indicated by the physiognomy, whilst the natural disposition may be of a diametrically opposite character. The fallaciousness of this mode of judging of mankind has been proverbial in all times. Whenever we attempt to decide upon a man's intellectual powers, by the rules laid down by Lavater, we are constantly deceived; and, in this respect, he has himself evidently fallen into the grossest errors.

What may be, not inappropriately, styled *medical physiognomy* or the changes of feature indicative of, and peculiar to, different diseases and stages of disease, is a subject of much moment, and has not met with sufficient attention. In diseases of infancy, in particular, the appearance of the contenance will often materially aid us in the discriminating the seat of the affection. There is a marked difference between the facial expression of one labouring under violent pain in the head, and of one suffering from excruciating pain in the abdomen, even in the adult. Lesser degrees of pain are, of course, disregarded, and it is only in severe cases, that physiognomy can be inservient to diagnosis; but, in the infant, which readily gives expression to any pain or uneasiness, the countenance is an excellent medium of discrimination, and will frequently indicate, at the first glance, the seat of the derangement. The character, too, of the countenance, in serious disease, as to anxiety, convulsion, &c., is often a subject of watchful interest with the physician.

Mute expression is not, however, restricted to the face, although, as we have remarked, in civilized man, whose nakedness is covered, we are shut out from the observation of many of the acts of this nature. During emotion, the skin, covering the body, may participate with that of the face, in its changes from pale to red; and it may be warm or cold, dry or bathed in perspiration, or, during particular depressing passions, may creep and exhibit the rough character of the *cutis anserina* or *goose skin*. Under particular emotions, the erectile tissues of the organs of generation, and of the nipple in the female, experience turgescence. All these changes are more or less concealed from view. We are, therefore, more familiar with the sight of those phenomena of expression, which affect the whole body, as regards its different attitudes and modes of progression. How tremulous and vacillating is the attitude of one labouring strongly under fear; and how different the port of the meek and lowly from that of the proud and haughty? In walking, we observe a similar difference; and can frequently surmise the character of the passion, whether exhilarating or depressing, under which a person, at a distance, may be labouring from the particularity of his progression:—

> "You may sometimes trace
> A feeling in each footstep, as disclosed
> By Sallust in his Catiline, who, chased,
> By all the demons of all passions, showed
> Their work even by the way in which he trode."—*Byron.*

Again, on the communication of sudden tidings of joy, we feel a desire to leap up, and to give way to the most wild and irregular motions; whilst the shrinking within ourselves, as it were, and the involuntary shudder, sufficiently mark the reception of a tale of horror.

Properly speaking, the subject of cranioscopy belongs to the function of expression, but it has already been considered under another head.

Many of the partial movements constitute an important part of the language of expression, especially with the savage, and with those unfortunates, who are shut out from the advantages of spoken language. In almost all nations, the motions of the head on the vertebral column are used as signs of affirmation or negation; the former being indicated by a sudden and short forward flexion of the head on the column; the latter, by a rapid and short rotation on the axis or vertebra dentata. The shoulders are shrugged, in testimony of impatience, contempt, &c.

The upper extremities are extensively employed as a part of conventional language, and were probably used for this purpose before speech was invented. The open and the closed hand are used to communicate different impressions to the observer; the pointed finger directs attention to the object we wish to indicate, &c. When persons are at such a distance from each other, that the voice cannot be heard, this is the only language they can have recourse to; and the various important inventions, by which we communicate our feelings to a distance, such as writing and telegraphing, belong to this variety of language.

For the deaf and dumb, our ordinary spoken language is translated into gestures, by which a conversation can be held, sufficient for all useful purposes; whilst the deaf, dumb, and blind, are mainly restricted to those gestures that are conveyed through their sense of touch.

Each acquired gesture is, like each acquired movement of the glottis, an evidence of the possession of intellect. The infant and the idiot have them not, because unable to appreciate their utility. The gestures resemble the spoken language in this and many other respects. The eye sees the gesture, to which the intellect attaches an idea, as it does to the sound conveyed by the organ of hearing;

and the will reproduces the gesture, in the same manner as it reproduces the sound heard.

The lower extremities are, also, slightly concerned in the function of expression. They are agitated when we are impatient, and incessantly changing their position. The foot is stamped upon the ground in anger; and, like the upper extremity, is employed to convey to the object that has aroused the emotion, the most unequivocal evidences of expression. Occasionally, the lower extremity is used as a part of conventional language, as when we tread upon the toes, to arouse attention, or to convey insult. Nor are the internal organs foreign to the function of expression. The respiratory movements are affected, the number of respirations being accelerated or retarded, or manifesting themselves under the different modifications of *sighing*, *yawning*, *laughing*, and *sobbing*. The heart, too, will throb, sometimes to such an extent, that its action is perceptible externally; or, it may be retarded or hurried in its pulsations, from a state of syncope or fainting to that of the most violent palpitation.

Lastly, the excretions, especially some of them, are greatly concerned in many of these moral changes. That of the tears is a well known and characteristic expression—of grief more especially, but occasionally of joy. The mind, however, may be so possessed by the emotion, that the ordinary power over the sphincter muscles is more or less destroyed, and the contents of the rectum are spontaneously evacuated. The action of the stomach is, at times, inverted; and, at others, the peristaltic action is augmented. Who has not felt, whilst labouring under anxiety or dread, the constant desire not only to evacuate the fæces, but also the urinary secretion?

It is obvious, from this detail, that there is scarcely a function, which does not *express* some participation, when the mind is engaged in deep emotion; and that it would be vain to attempt to depict the various forms, under which these manifestations may occur. What has been said will suffice to attract attention to the subject, which is not devoid of interest to the anthropologist.

In conclusion, we may refer to the question, which has often been agitated, whether these rapid and violent movements, that characterize the expression of emotions, be *instinctive* or *natural* signs of the passion existing in the mind; or whether they be not voluntary, muscular exertions, called for by the stress of the case, and constituting the means of resistance, or belonging simply to the outward manifestation of the inward emotion. The supporters of the latter view contend, that the various changes of facial expression or of gesture, which accompany the different mental emotions and indicate their character, are, in all cases, the effect of habit, or are suddenly excited to operate some beneficial purpose. It is difficult, however, to regard the different concomitants of the passion as separate from it. Without them, the expression is incomplete; and we observe the different gestures similarly developed in all the various races of mankind, when labouring under the same mental contention. We must, consequently, regard the expressions as constituting a natural language, in which each has its own appropriate sign; and this view is signally confirmed by the fact, that there are certain muscles of the face, which seem, in our existing state of knowledge, to be exclusively destined for expression; those about the eyebrow and angles of the mouth for example, on which we have already expatiated. When the triangularis muscle, N, Fig. 34, and the levator menti, P, combine in their action, an expression is produced, which is peculiar to man; the angle of the mouth is drawn down, and the lip arched and elevated; hence the most contemptuous and proud expression.

A question of a different character has, however, been mixed up with this:—whether the infant is capable instinctively or naturally of comprehending the difference between the facial expressions of kindness or of frowns; some believing, that smiles are merely considered by it to be expressions of kindness, because accompanied by endearments, and frowns as proofs of displeasure, because followed by punishment. It is certain, however, that the infant interprets the countenance long before it can trace such sequences in its mind; but this does not remove the difficulty. The face of one, whom it has not been accustomed to see, will, at a very early period, impress it unfavourably, even although the countenance may be unusually prepossessing; and the alteration of the ordinary expression of the maternal countenance may be attended with similar results. It is difficult, indeed, to comprehend how the child should be capable of discriminating between the smile and the frown, when first presented to it. That organs may be associated, in the expression of any encephalic act, is intelligible; but that an act of judgment can be executed naturally or instinctively, appears inexplicable. Sir Charles Bell, who maintains the doctrine of the instinctive character of the expression of human passions, rejects the notion of instinctive expression in the face of the quadruped, contending that, even in the passion of rage, which is the most strongly marked of all, the changes, that occur in the features, are merely motions, accessary to the great object of opposition, resistance, and defence. "In carnivorous animals," he remarks, "the eyeball is terrible, and the retraction of the flesh of the lips indicates the most savage fury. But the first is merely the excited attention of the animal, and the other a preparatory exposure of the canine teeth." It appears, however, to be a sufficient answer to this view, that no such expression is ever witnessed in other cases of excited attention, or in the simple exposure of the canine teeth, when the animal is devouring its food; unless, indeed, the repast be effected, during the prevalence of the passion.

On a former occasion, it was remarked, that the encephalon is exclusively concerned in the production of the different passions. and that the parts to which they are usually referred, attract our attention to them principally, in consequence of the sensation, which accompanies them, being there chiefly experienced. The same may be said of the different gestures, that accompany the various emotions. They are dependent upon the influence, exerted by the function of sensibility on the other functions. Gall, in his system, has feebly attempted to show, that each gesture has a reference to the encephalic situation of the organ, concerned in the production of the emotion of which it is a concomitant. The idea was suggested to him, he asserts, by the fact, which he had observed, a thousand times, that in fractures of the skull, the hand, (very naturally we should think,) was carried mechanically to the seat of the fracture. He farther remarks, that the organs of the memory of words and of meditation are seated in the forehead; and that the hand is carried thither, whenever we are engaged in deep study:—that the organ of religious instinct corresponds to the vertex, and hence, in the act of prayer, all the gestures are directed towards that part of the body. Like every professed systematist, Gall is here pushing his principles *ad absurdum*. They are, indeed, controverted by facts. The hand is usually carried, not to the part of the encephalon, in which any passion is effected, but to the part of the body in which its more prominent effects are perceptible, as to the region of the stomach or heart; whilst, frequently, the gesture is referable to the determinate action, which must be regarded as a necessary effect of the passion.

Finally, *poetry* and *painting* belong properly to the varieties of expression; but they are topics, that do not admit of elucidation by physiology.

With this subject we terminate the history of the animal functions. All these have the common character of being periodically suspended by sleep. By many physiologists, this function has, therefore, been examined in this place; but as the nutritive and generative functions are, likewise, greatly influenced by sleep, we shall follow the example of Magendie, and defer its study, until we have inquired into those functions.

CLASS II.

NUTRITIVE FUNCTIONS.

The human body, from the moment of its formation to the cessation of existence, is undergoing incessant decay and renovation—decomposition and composition:—so that, at no two periods, can it be said to consist of exactly the same constituents. The class of functions, about to engage attention, embraces those that are concerned in effecting such changes. They are seven in number:—*digestion*, by which the food, received into the stomach, undergoes such conversion, as fits it for the separation of its nutritious and excrementitious portions: *absorption*, by which this nutritious portion, as well as other matters, is conveyed into the mass of blood: *respiration*, by which the products of absorption and the venous blood are converted into arterial blood: *circulation*, by which the vital fluid is distributed to every part of the system: *nutrition*, by which these intimate changes of composition and decomposition are accomplished: *calorification*, by which the system is enabled to resist the effects of greatly elevated or depressed atmospheric temperature, and to exist in the burning regions within the tropics, or amidst the arctic snows: and *secretion*, by which various fluids and solids are separated from the blood; some to serve useful purposes in the animal economy; others to be rejected from the body.

OF DIGESTION.

The food, necessary for animal nutrition, is rarely found in such a condition as to be adapted for absorption. It has, therefore, to be subjected to various actions in the digestive organs; the object of which is to enable the nutritive matter to be separated from it. These various actions constitute the function of digestion; in the investigation of which we shall commence with a brief description of the organs concerned in it. These are numerous and of a somewhat complicated nature.

Anatomy of the Digestive Organs.

The human digestive organs consist of a long canal, varying considerably in its dimensions in different parts, and communicating externally by two outlets,—the *mouth* and the *anus*. It is usually divided into four chief portions—the *mouth*, *pharynx* and *œsophagus*, *stomach*, and *intestines*. These we shall describe in succession.

1. The *mouth* is the first cavity of the digestive tube, and that into which the food is immediately received, and subjected to the action of the organs of mastication and insalivation. Above and below, it is circumscribed by the jaws, and laterally by the cheeks;—anteriorly, by the lips and their aperture, constituting the mouth proper; and, posteriorly, it communicates with the next portion of the tube,—the pharynx. It is invested by a mucous exhalant membrane, which is largely supplied with follicles; and into it the ducts from the different salivary glands pour their secretion.

Mastication is of essential importance to digestion, and an inattention to this circumstance is a common cause of dyspepsia. In all animals, furnished with distinct digestive organs, some means exist for comminuting the food, and enabling the stomach to act with greater facility upon it. These consist, for the most part, as in man, of the jaws: the teeth fixed into the jaws, and of muscles by which the jaws are moved.

The jaws chiefly determine the shape and dimensions of the mouth; the *upper* forming an essential part of the face, and moving only with the head; the *lower*, on the contrary, possessing great mobility.

Each of the jaws has a prominent edge, forming a semicircle, in which the teeth are implanted. This edge is called the *alveolar arch.*

The *teeth* are small organs, of a density superior to bone; and covered externally by a hard substance, called *enamel.* By many, they have been regarded as bone, but they differ from it in many essential respects, although they resemble it in hardness and chemical composition. At another opportunity, we shall inquire into their origin, structure and developement. We may merely remark, at present, that by De Blainville they are looked upon as analogous to the corneous substances, which develope themselves in the tissue of the skin. He assimilates them to the hair, and believes, that they are primarily developed in the substance of the membrane lining the mouth, in the tissue of the gums; and that their enclosure in the substance of the alveolar arches of the jaws occurs subsequently.

The number of the teeth is sixteen in each jaw. These are divided into classes, according to their shape and use. There are, in each jaw, four *incisores:* two *cuspidati* or *canine* teeth; four *bicuspidati;* and six *molares* or *grinders.*

Each tooth has three parts;—the *crown*, *neck*, and *fang*, or *root:* the first being the part above the gum; the second that embraced by the gum; and the third the part contained in the *alveolus* or socket.

The crown varies in the different classes. In the incisors, it is wedge-shaped; in the canine, conical; and in the molar, cubical. In all, it is of extreme hardness, but in time wears away by the constant friction to which it is exposed.

The incisor and canine teeth have only one root; the molares of the lower jaw, two; and of the upper, three. In all cases, they are of a conical shape, the base of the cone corresponding to the corona, and the apex to the bottom of the alveolus. The alveolar margin of the jaws is covered by a thick, fibrous, resisting substance, called the *gum*. It surrounds accurately the inferior part of the crown of the tooth, adheres to it strongly, and thus adds to the solidity of the junction of the teeth with the jaws. It is capable of sustaining considerable pressure without inconvenience.—But we shall have to return to the subject of the teeth hereafter.

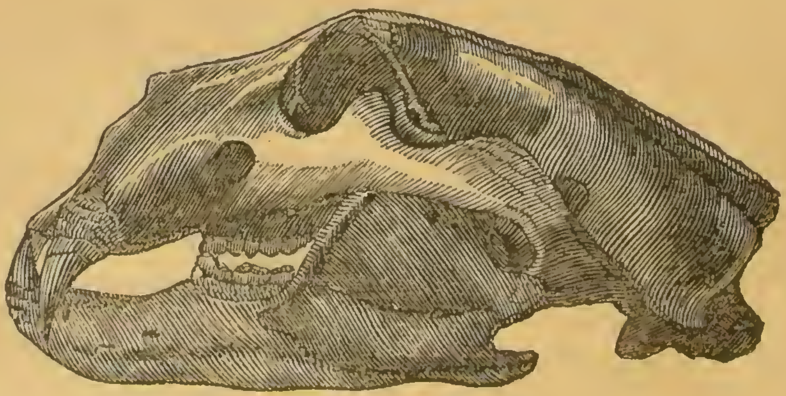
The articulation of the lower jaw is of such a nature as to admit of depression and elevation; of horizontal motion forwards, backwards and laterally; and of a semi-rotation upon one of its condyles.

The muscles, that move it, may be thrown into two classes;—the *elevators* and *depressors*. These, by a combination of their contraction, can produce every intermediate movement between elevation and depression. The raisers or levator muscles of the jaw extend from the cranium and upper jaw to the lower. They are four in number, on each side,—the *temporal*, and *masseter*, which are entirely concerned in the function; the *external pterygoid*, which, whilst it raises the jaw, carries it, at the same time, forward and to one side; and the internal *pterygoid*, which, according as it unites its action with the temporal or with the external pterygoid, is an elevator of the jaw or a lateral motor.

The depressors may be divided into immediate and mediate, according as they are, or are not, attached to the lower jaw itself. There are only three of the former class: 1, the *digastricus*, the anterior fasciculus of which, or that which passes from the os hyoides to the lower jaw, depresses the latter; 2, the *genio-hyoideus*; and, 3, the *mylo-hyoideus*, all of which concur in the formation of the floor of the mouth.

The indirect or mediate depressors are all those, that are situated between the trunk and the lower jaw, without being directly attached to the latter;—as the *thyro-hyoideus*, the *sterno-thyroideus*, and the *omo-hyoideus*; the names of which indicate their origin and insertion. These, in the aggregate, form a muscular chain, which, when it makes the trunk its fixed point, depresses the lower jaw. The arrangement of the elevators and depressors is such, that the former predominate over the latter; and hence during sleep the jaws continue applied to each other, and the mouth is, consequently, closed.

Fig. 94.



Skull of the Polar Bear.

The human organs of mastication hold an intermediate place between those of the carnivorous and herbivorous animal. In the carnivorous animal, which has to seize hold of, and retain its prey between its teeth, the jaws have considerable strength; and the movement of elevation is all that is practicable; or, at least, that can be effected to any extent. This is dependent upon organization. The condyle is broader from side to side, which prevents motion in that direction; the glenoid cavity is very deep, so that the head of the jaw bone cannot pass out from it; and it is, moreover, fixed in its place by two eminences before and behind. The muscular apparatus is also so arranged as to admit of energetic action on the part of the muscles that raise the jaw; but of scarcely any in a horizontal direction. The deep depressions, in the regions of the temporal and masseter muscles, indicate the large size of these muscles in the purely carnivorous animal; whilst the pterygoid muscles are extremely small. The teeth, too, are characteristic; the molares being comparatively small, at the same time, that they are much more pointed. On the other hand, the cuspidati are remarkably large; and the incisors, in general, acuminated.

Fig. 95.

Skull of the Cow.

The herbivorous animal has an arrangement the reverse of this. The condyle or head of the lower jaw is rounded; and can, therefore, be moved in all directions; and as easily horizontally as up and down. The glenoid cavity is shallow, and yields the same facilities. The articulation, which is very close in the carnivorous animal, is here quite loose. The elevator muscles are much more feeble; the temporal fossa is less deep; the zygomatic arch less convex; and the zygomatic fossa less extensive. On the other hand, the pterygoid fossa is ample, and the muscles of the same name largely developed. The molares are large and broad; and their magnitude is so great as to require, that the jaw should be much elongated, in order to make room for them.

The joint of the lower jaw has, in man, solidity enough for the jaws to exert considerable pressure with impunity; and laxity enough that the lower jaw may execute horizontal movements. The action of the levator muscles is the most extensive; but the lateral or grinding motion is practicable to the necessary extent; and the muscles of both kinds have a medium degree of developement. The teeth, likewise, partake of the characteristics of those of the carnivorous and herbivorous animals; twelve—the canine teeth and lesser molares—corresponding to those of the carnivorous, and twenty—the incisors and larger molares—to those of the herbivorous.

The tongue must be regarded as an organ of mastication. It rests horizontally on the floor of the mouth; is free above, anteriorly, and, to a certain extent, beneath and at the sides. Behind, it is united to the epiglottis by three folds of the mucous membrane of the mouth; and is supported at its base by the os hyoides, with which it participates in its movements. Of the tongue, as the organ of taste and articulation, we have already spoken. We have only, therefore, to describe the os hyoides and its attachment to that bone. The hyoid bone has, as its name imports, the shape of the Greek letter υ, (upsilon,) the convex part being before. Fig. 86.) It is situated between the tongue and the larynx; and is divided into *body* or *central part;* and into *branches*, one extremity of which is united to the body by an intermediate cartilage, that admits of slight motion; whilst the other is free, and is called the *greater cornu.* Above the point, at which the branch is articulated with the body, is an apophysis or process, called the *lesser cornu.*

The os hyoides is united to the neighbouring parts by fibrous organs, and by muscles. The former are;—*above*, the *stylo-hyoid ligament*, which extends from the lesser cornu of the bone to the styloid process of the temporal bone; *below*, a fibrous membrane, called the *thyro-hyoid*, passing between the body of the bone and the thyroid cartilage; and two ligaments, extending from the greater cornu of the hyoid bone to the thyroid cartilage, called the *thyro-hyoid.* Of the muscles; some are above the hyoid bone, and raise it;—viz. the *genio-* and *mylo-hyoideus*, already referred to; the *stylo-hyoid*, and some fibres of the *middle constrictor of the pharynx.* Others are below, and depress it. They are the *sterno-thyro-hyoideus*, *omo-hyoideus*, and *sterno-thyroideus.*

The base of the tongue is attached to the body of the bone by a ligamentous tissue, and by the fibres of the *hyoglossus* muscle.

Among the collateral organs of mastication are those that secrete the saliva, and the various fluids, which are poured out into the mouth,—constituting together what has been termed the *apparatus of insalivation.* These fluids proceed from different sources. The mucous membrane of the mouth, like other mucous membranes, exhales a serous or albuminous fluid, besides a mucous fluid secreted by the numerous follicles contained in its substance. Three glands likewise exist, on each side, destined to secrete the *saliva*, which is poured into the mouth by distinct excretory ducts. They are the *parotid*, *submaxillary*, and *sublingual.* The first is situated between the ear and the jaw; and its excretory duct opens into the mouth opposite the second small molaris of the upper jaw. By pressing upon this part of the cheek, the saliva can be made to issue in perceptibly increased quantity into the mouth.

The submaxillary gland is situated beneath the base of the jaw; and its excretory duct opens into the mouth at the side of the frænum linguæ.

The sublingual gland is situated under the tongue, and its excretory ducts open at the sides of the tongue.

These glands are constantly pouring saliva into the mouth; and it has been presumed, that the fluids secreted by them may differ from each other in physical and chemical characters. Such, at least, has been the view of some as regards the sublingual, the texture of which more nearly resembles that of the compound follicles than of the glands; but the circumstance has not been proved by any direct experiment. The saliva, as met with, is a compound of every secretion poured into the mouth; and it is such fluid which has alone been subjected to analysis. The secretion of the saliva, and its various properties belong, however, to another division of the nutritive functions.

The two apertures of the mouth are the *labial* and *pharyngeal*. The former, as its name imports, is formed by the lips, which consist externally of a layer of skin, are lined internally by a mucous membrane, and, in their substance, contain numerous muscles, already described under the head of the *Gestures*.

These muscles may be separated into *constrictors* and *dilators*; the *orbicularis oris* being the only one of the first class, and the antagonist to the others, which are eight in number, on each side—the *levator labii superioris alæque nasi*, the *levator labii superioris proprius*, the *levator anguli oris*, the *zygomaticus major*, the *zygomaticus minor*, the *buccinator*, the *triangularis*, and the *quadratus menti*. (Fig. 34.) To the two last muscles are added some fibres of the *platysma myoides*.

The *pharyngeal opening* is smaller than the labial, and of a quadrilateral shape. It is bounded, above, by the *velum palati* or *pendulous veil of the palate*; below, by the base of the tongue; and, laterally, by two muscles, which form the *pillars of the fauces*. The pendulous veil is a musculo-membranous extension, constituting a kind of valve, attached to the posterior margin of the bony palate, by which all communication between the mouth and pharynx, or between the pharynx and nose, can be prevented. To produce the first of these effects it becomes vertical; to produce the latter, horizontal.

At its inferior and free margin, it has a nipple-like shape, which portion bears the name of *uvula*. It is composed of two mucous membranes and of muscles. One of the membranes—that forming its anterior surface—is a prolongation of the membrane lining the mouth, and contains numerous follicles; the other, forming its posterior surface, is an extension of the mucous membrane lining the nose, and is redder, and less provided with follicles than the other.

The muscles, that constitute the body of the velum palati, are—the *circumflexus palati* or *spheno-salpingo-staphylinus* of Chaussier; the *levator palati* or *petro-salpingo-staphylinus;* and the *azygos uvulæ* or *palato-staphylinus.*

The velum is moved by eight muscles. The two *internal pterygoid* raise it; the two *external pterygoid* stretch it transversely; the two *palato-pharyngei* or *pharyngo-staphylini*, and the two *constrictores isthmi faucium* or *glosso-staphylini* carry it downwards.

The four last muscles form the pillars of the fauces;—the two first the posterior pillars; and the two last the anterior; between which are situated the *tonsil glands* or *amygdalæ*, which are not really glandular, but composed of a congeries of mucous follicles.

2. The *pharynx* and *æsophagus* are two muscular canals, forming the media of communication between the mouth and stomach, and conveying the food from the former of these cavities to the latter.

The *pharynx* has the shape of an irregular funnel; the large opening of the funnel looking towards the mouth and nose, whilst the under and smaller end terminates in the œsophagus. Into its upper part, the nasal fossæ, Eustachian tubes, mouth, larynx, and œsophagus open. It is inservient to useful purposes in the production of voice, in respiration, and audition, as well as in digestion; and extends from the basilary process of the occipital bone, to which it is attached, as far as the middle part of the neck. Its transverse dimensions are determined by the os hyoides, the larynx, and the pterygo-maxillary apparatus, to which it is attached. It is lined by a mucous membrane, less red than that which lines the mouth, but more so than that of the œsophagus, and of the rest of the digestive tubes; and it is remarkable for the developement of its veins, which form a very distinct net-work. Around this is the muscular layer, the circular fibres of which are often divided into three muscles,—the *superior*, *middle* and *inferior constrictors.* The longitudinal fibres form part of the *stylo-pharyngei* and *palato-pharyngei* muscles.

Fig. 96.

Section of the æsophagus. a b. The interior circular fibres. c. The external longitudinal fibres.

The pharynx is raised by the action of the two last muscles, as well as by all those that are situated between the lower jaw and os hyoides, which cannot raise the latter without, at the same time, raising the larynx and pharynx. These muscles are;—the *mylo-hyoideus*, *genio-hyoideus*, and the anterior belly of the *digastricus.*

The *æsophagus* is a continuation of the pharynx; and extends to the stomach, where it terminates. Its shape is cylindrical, and it is connected with the surrounding parts by loose and extensible cellular tissue, which yields readily to its movements. On entering the abdomen, it passes between the pillars of the diaphragm, with which it is intimately united. The mucous membrane, lining it, is pale, thin, and smooth; forming longitudinal folds, well adapted for favouring the dilatation of the canal. Above, it is confounded with that of the pharynx; but below, it forms several digitations, terminated by a fringed extremity, which is free in the cavity of the stomach. It is well supplied with mucous follicles. The muscular coat is thick, and its texture denser than that of the pharynx:—it cannot, like that of the pharynx, be separated into distinct muscles, but consists of circular and longitudinal fibres; the former of which are more internal, and very numerous; the latter external, and less numerous.

The marginal figure exhibits the situation and arrangement of the two sets of fibres.

Fig. 97.

The stomach seen externally.

A A. Anterior surface.—B. Enlargement at the lower part.—D. Cardiac orifice.—E. Commencement of duodenum.—F and C. Coronary vessels.—H. Omentum.

3. The *stomach* is situated in the cavity of the abdomen, and is the most dilated portion of the digestive tube. It occupies the epigastric region, and a part of the left hypochondre. Its shape has been compared, not inappropriately, to that of the bag of a bag-pipe.

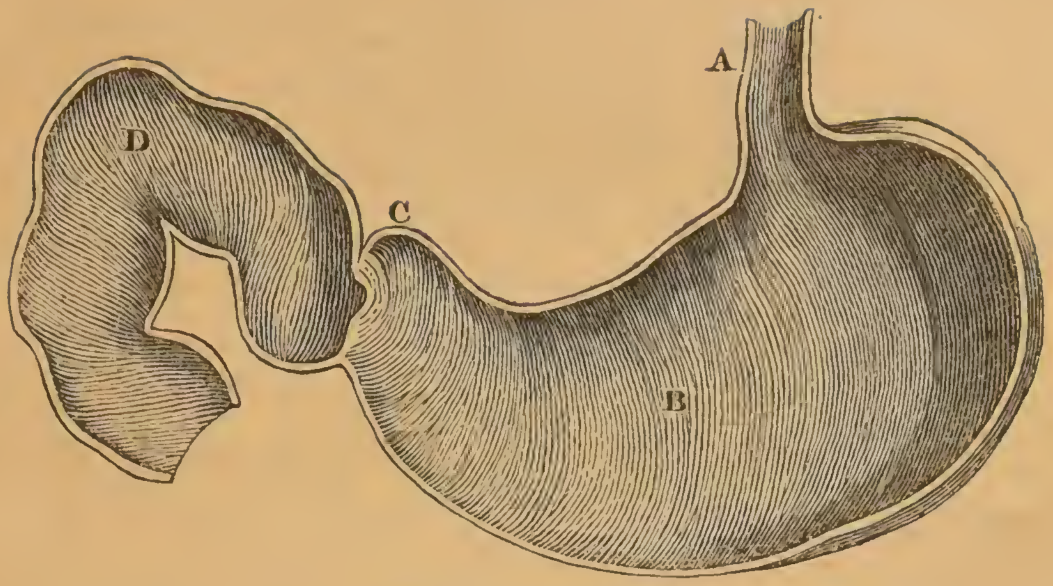
It is capable of holding, in the adult male, when moderately distended, about three pints. The left half of the organ has always much greater dimensions than the right. The former has been called the *splenic portion*, because it rests upon the spleen; the latter the *pyloric portion*, because it corresponds to the pylorus. The inferior border of the *stomach*, which is convex, is termed the *great curvature* or *arch;* the superior border, the *lesser curvature* or *arch.* The two orifices are the *œsophageal, cardiac* or *upper orifice*, formed by the termination of the œsophagus; and the *intestinal, pyloric*, or *inferior orifice*, which communicates with the small intestine.

The three coats, which constitute the parietes of the stomach, are arranged in a manner the most favourable for permitting variation in the size of the organ. The outermost or *peritoneal coat* consists of two laminæ, which adhere but slightly to the organ, and extend beyond it, where they form the *epiploons* or *omenta*, the extent of which is in an inverse ratio to the degree of distention of the stomach. The *omentum majus* or *gastro-colic epiploon* is the part that hangs down from the stomach in Fig. 97.

The mucous or lining membrane is of a whitish, marbled, red appearance: having a number of irregular folds, situated especially along the inferior and superior margins of the organ. These folds are evident, also, at their splenic extremity; and are more numerous and marked, the more the stomach is contracted. They are radiated towards the cardiac, longitudinal towards the pyloric, orifice. This membrane, like every other of the kind, exhales an albuminous fluid from a multitude of delicate villi, which are as perceptible in the stomach as in any part of the digestive tube. It contains, also, many follicles, which are especially abundant in the pyloric partion. Several, also, exist in the vicinity of the cardiac orifice, but in the rest of the membrane they are few in number.

The *pylorus*, or the part at which the stomach terminates in the small intestine, is marked, externally, by a manifest narrowness, as at C, Fig. 98. Internally, the mucous membrane forms a circular fold, which has been called the *valve of the pylorus*, between the two laminæ of which, a dense, fibrous tissue exists. This has been called, by some authors, the *pyloric muscle.*

Fig. 98.



Section of the stomach, &c.

A. The œsophagus.—B. The stomach.—C. The pylorus.—D. The duodenum.

The *muscular coat* of the stomach, which is situated without the mucous coat,—as in the parts of the digestive tube already described,—consists of several laminæ of fibres, less distinct than those of the œsophagus; or rather more irregularly distributed. The most common opinion is, that there are three laminæ; some forming an external, longitudinal series; a middle, transverse stratum; and an inner stratum with the fibres running longitudinally. Both circular and longitudinal fibres are separated from each other, especially in the splenic portion; the separation augmenting or diminishing with the varying size of the stomach.

The blood-vessels and nerves of the stomach are more numerous than those of any other organ of the body.

The arteries are disposed along the curvatures. On the lesser curvature are—the coronaria ventriculi, and the pyloric branch of the hepatic artery: on the great curvature, the right gastro-epiploic, which is a branch of the hepatic; and the left gastro-epiploic,—a branch of the splenic. The splenic artery, too, furnishes numerous branches to the left *cul-de-sac*, behind. These are called *vasa brevia* or *gastro-splenic.*

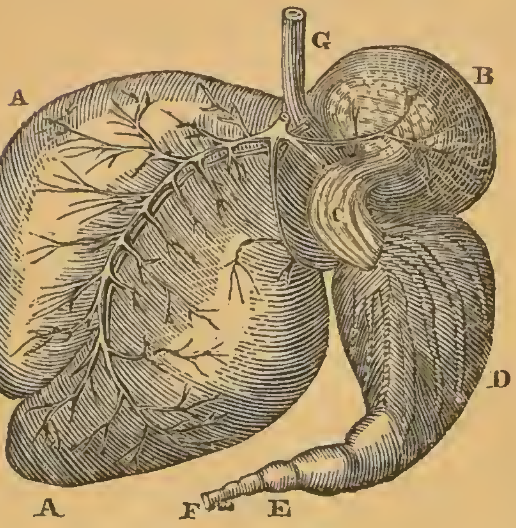
The nerves of the stomach are of two kinds. Some proceed from the great sympathetic, from the cœliac plexus, and accompany the arteries through all their ramifications. Others are furnished by the pneumo-gastric or eighth pair; the two nerves of which surround the cardiac orifice like a ring.

The number of the nerves, and the variety of sources whence they are derived, explains the great sympathetic influence exerted upon the stomach by affections of other parts of the system. It sympathizes, indeed, with every protracted morbid change in the individual organs; and hence it was termed, by Hunter, the *centre of sympathies.*

Like the teeth, the human stomach holds a medium place between that of the carnivorous, and herbivorous animal. As the former make use of aliment, which is more readily assimilated to their own nature, and more nutritious, it is not necessary, that they should take food in such large quantity as the latter, or that it should remain so long in the stomach. On this account, the organ is generally of much smaller size. On the other hand, the herbivora, subsisting solely upon grass, which contains but a small quantity of nutritious matter, and that not easy of assimilation, it is important, that the quantity taken in should be ample, that it should remain for some time in the organ, subjected to the action of its secretions; and, in the ruminant class, be returned into the mouth, to undergo fresh mastication.

In this class, the stomach, taken altogether, is of prodigious extent. In the ox, which we may take as an example of the general structure of the organ, it consists of four separate compartments. The first stomach, A A, Fig. 99, is the *ventriculus* or *paunch*, which is much the largest of the four. Externally, it has two sacs or appendices; and, internally, it is slightly divided into four compartments.

Fig. 99.



Stomach of the ox.

A A. The paunch.—B. The reticulum.—C. The omasum.—D. The abomasum.—E. The pylorus.—F. Duodenum.—G. Œsophagus.

The second stomach is the *reticulum*, *bonnet*, or *honeycomb bag*, B, which appears to be a globular appendix to the paunch. It is situated to the right of the œsophagus, G, and has usually a thicker muscular coat than the paunch. Its inner surface is arranged in irregular pentagonal cells, and is covered with fine papillæ.

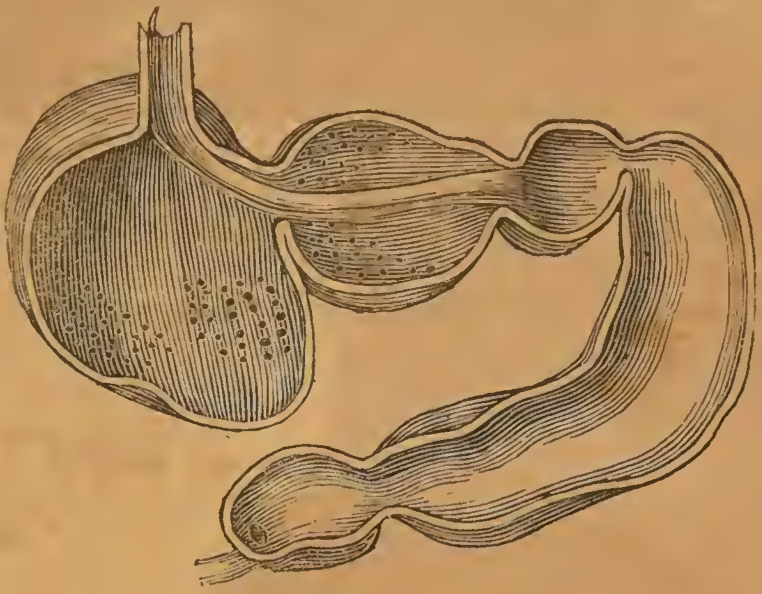
The third stomach, C, is the smallest, and is called *omasum*, or *many plies*. It is of a globular shape, and has a thinner muscular coat than the former. It consists of numerous broad laminæ, sent off from the internal coat, running in a longitudinal direction, alternately varying in breadth, and covered with small granular papillæ.

The fourth stomach, D, is the *abomasum*, *ventriculus intestinalis*, or *caillette*. It has a pyriform shape, and is next in size to the paunch. It has a large longitudinal rugæ, covered with villi. The muscular coat is still thinner than that of the former. This stomach is the only one that resembles the human organ; and, in the young of the ruminant animal, with the milk curdled in it, forms the *runnet*. The property of curdling milk is, however, possessed by all digestive stomachs.

The inner surface of the three first stomachs is covered with cuticle; whilst that of the fourth is lined by a true mucous or secreting membrane.

There is in the anterior arrangement of the stomachs of the ruminant animal, a singular provision, by which the food can be either received into the first and second stomachs or be carried on into the third, if its character be such as to be fitted at first for the action of the omasum.

Fig. 100.



Interior view of the stomach of the ruminant animal.

From the œsophagus, in Fig. 100, a gutter passes into the second and third stomachs. The third leads into the fourth by a narrow opening, and the fourth terminates in the duodenum, which has a pylorus at its origin. When the animal eats solid food, this is, after slight mastication, passed into the paunch, and from thence, by small portions, into the second stomach. When this has become mixed with fluid, and kept for some time at a moderately high temperature, a morsel is thrown back with velocity from the stomach into the mouth, where it is "ruminated," and then swallowed and passed on into the third stomach,—the groove or gutter being so contracted as to form a channel for its passage through the two first. In the third and fourth stomachs, more especially in the latter, true digestion takes place.

When the food is of such a character as not to require rumination it can be sent on directly into the third stomach, by the arrangement just described.

In the bird tribes, we see an admirable adaptation of the structure to the functions, which the digestive organs have to execute. Animals of this class may be divided into the granivorous and the carnivorous. It is in the former, that we are so much impressed with the organization of this part of their economy.

The grain, on which they feed, although more nutritious than the grass, which constitutes the aliment of the herbiforous quadruped, requires equal difficulty in being assimilated to the nature of the being it has to nourish. Added to this, it is in such a condition, that the juices of the digestive organs cannot readily act upon it. The bird, having no masticatory apparatus within the mouth, the grain must of necessity be swallowed whole. But we find, that lower down in the alimentary tube a powerful masticatory apparatus exists, which has frequently been considered as a part of the digestive stomach, but really seems destined for mastication only. The following is the arrangement of their gastric apparatus.

Fig. 101.

Gastric apparatus of the Turkey.

Fig. 102.

Interior of the Gastric apparatus of the Turkey.

The œsophagus terminates at the bottom of the neck in a large sac—the *ingluvies*, or *crop* or *craw*—which is of the same structrue with the œsophagus, but thinner. On the inner side side of the crop are numerous glands, with very distinct orifices in large birds, which secrete a fluid to assist in the solution of the food. To the crop succeeds another cavity, in the shape of a funnel, called the *ventriculus succenturiatus*, *infundibulum* or *second stomach*. This is seated in the abdomen, and is generally smaller than the former. It is usually thicker than the œsophagus, partly owing to its numerous glands, which are very large and distinct in many birds. In the ostrich they are as large as the garden-pea, and have very manifest orifices. The infundibulum terminates in the *ventriculus callosus*, *gizzard* or *third stomach*,—the most curious of all the parts of the apparatus.

In figures 101 and 102, we have an external and internal view of the gastric apparatus of the turkey; *a*, representing the œsophagus immediately below the crop, covered with a cuticle; *b*, the openings of the gastric glands in the second stomach, placed on a surface, that has no cuticular covering; *c*, horny ridges, between the gastric glands and the lining of the gizzard; *d*, a minutely granulated surface, between the cavity of the gizzard and the duodenum; and *e*, the inner surface of the duodenum. The figure accurately represents the mode in which the second stomach terminates in the gizzard, and the latter in the duodenum; the gizzard forming a kind of pouch depending from the alimentary canal. The gizzard is usually of a globular figure, flattened at the sides, and is considered to consist of four muscles, remarkable for their great thickness and strength;—a large hemispherical pair at the sides and a small pair situated at the extremities of the stomach. The gizzard is covered, externally, by a beautiful tendinous expansion; and is lined by a thick, strong, callous coat, which appears to be epidermeous in its character. On this are irregularities, adapted to each other on the opposite surfaces. The cavity of the organ is remarkably small, when compared with its outward magnitude, and its two orifices, represented in Fig. 101, are very near each other.

In the pouch, formed by the small muscles at the lower part of the gizzard, numerous pebbles are contained, which seem to be indispensable to the digestion of certain tribes, by acting as substitutes for teeth. In the gizzard of the turkey, Mr. Hunter counted two hundred; in that of the goose one thousand.

The prodigious power, with which the *digastric muscle*, as it has been termed, acts, and the callous nature of the cuticle, are strikingly manifested by certain experiments, instituted by the *Academia del Cimento*, and by Redi, Réaumur, and Spallanzani. They compelled geese and other birds to swallow needles, lancets, and other hard and pointed substances. In a few hours afterwards, the birds were killed and examined. The needles and lancets were uniformly found broken off and blunted, without the slightest injury having been sustained by the stomach.

In the carnivorous bird, the food being readily assimilated, in consequence of its analogy to the substance of the animal, the gastric apparatus is as simple as it is in the carnivorous mammalia. The œsophagus is of great size for receiving the large substances swallowed by these animals, and for enabling the feathers and other matters, that cannot be easily digested, to be rejected by the mouth. The stomach is a mere musculo-membranous sac; but the secretion from it is of a potent character, so as to enable the animal to dispense with mastication, and yet to admit of the stomach and intestines being disposed within a small compass, so as to give them the necessary lightness to fit them for flight.

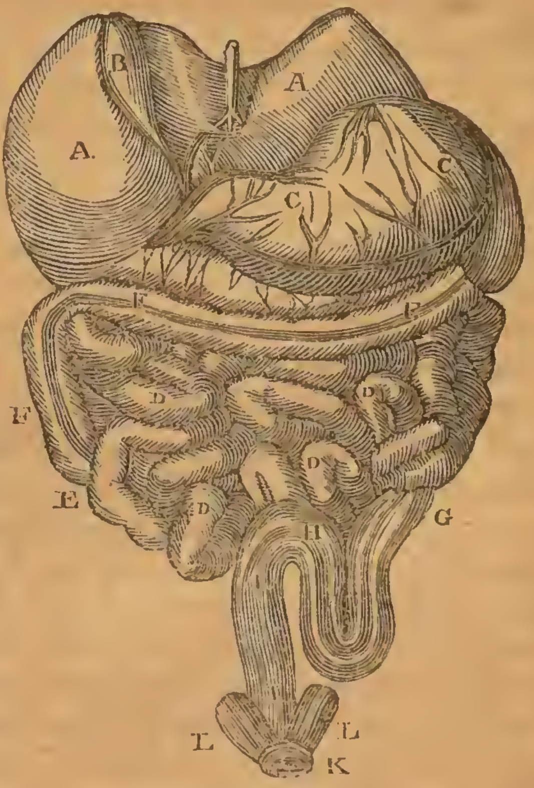
We can thus, from organization, generally discover the kind of food for which an animal is naturally destined;—in other words, we can say whether it is naturally granivorous, or carnivorous. There are some striking facts, however, exhibiting the signal changes exerted, even on organization, by restricting an animal to diet of a different character from that to which it has been accustomed; or to one which is foreign to its nature. In birds of prey, the digastric muscle has the bellies, which compose it, so weak, that, according to Sir Everard Home, nothing but an accurate examination can determine its existence. But if a bird of this kind, from want of animal food, be compelled to live upon grain, the bellies of the muscle become so large, that they would not be recognized as belonging to the stomach of a bird of prey.

Mr. Hunter kept a sea-gull for a year upon grain; and found the strength of the muscle very much augmented.

This wondrous adaptation of structure to the kind of food, which the animal is capable of obtaining, is elucidated in the cases of the South American and the African ostrich. The former is the native of a more productive soil than the latter; and, accordingly, the gastric glands are less complex and numerous; and the triturating organ is less developed.

4. *The intestines* are the lowest portion of the digestive apparatus; constituting a musculo-membranous canal, which extends from the pyloric orifice of the stomach to the anus.

Fig. 103.



Abdominal viscera.

A, A. The liver.—B. The gall bladder.—C, C. The stomach.—D, D, D, D. The small intestines.—E. Commencement of the large intestines.—F, F, F. The colon.—G, H. Sigmoid flexure of the colon.—I, I. Rectum.—K. Anus with sphincter ani.—L, L. Levatores ani.

The human intestines are six or eight times longer than the body; and hence the number of convolutions in the abdominal cavity. They are attached to the vertebral column by folds of the peritoneum, called the *mesentery;* and according to the length of these folds or duplicatures, the intestine is bound down, or floats in the abdominal cavity. Their structure is nearly alike throughout: a *mucous* membrane lines them: immediately without this is a *muscular* coat; and, externally, a *serous* coat, formed by a prolongation of the peritoneum. The mucous membrane is soft and velvety, and is the seat of a similar secretion to that of other membranes of the same class. The muscular coat is composed of two planes of fibres, so united, that they cannot be separated,—the innermost consisting of circular, and the outermost of longitudinal fibres; the arrangement of which differs in the small and large intestines. The serous or peritoneal coat receives the intestine between two of its laminæ, which, in their passage to it, form the *mesentery*. The serous coat only comes in direct contact with the intestine at the sides and forepart. Behind, or on the mesenteric side, is a vacant space, by which the vessels and nerves reach the intestine. These form their first net-work between the serous and muscular coats; their second between the muscular and mucous.

Between the upper four-fifths of the intestinal canal, and the lower fifth, there is a well-marked distinction; not only as regards structure and magnitude, but function. This has given occasion to a division of the canal into the *small intestine*, and the *large;* and these, again, have been subdivided in the various modes, which will successively fall under consideration.

As the *small intestine* fills so large a portion of the whole intestinal canal, its convolutions occupy considerable space in the abdominal cavity,—in the middle, the umbilical, and the hypogastric regions,—and terminate—in the right iliac region—in the large intestine, (see Fig. 103.) Its calibre differs in different parts; but it may be regarded on the average as about one inch. It is usually divided, arbitrarily, into three parts;—the *duodenum*, *jejunum*, and *ileum*.

The *duodenum* is so called, in consequence of its length having been estimated at about twelve fingers' breadth. It is larger than the rest of the small intestine; and has hence received, also, the name of the *second stomach*, and of *ventriculis succenturiatus*. It is more firmly fixed to the body than the other intestines; and does not, like them, float loosely in the abdomen. In its course, until its termination in the jejunum, it describes a kind of Italic *c*, the concavity of which looks to the left. From this shape it has been separated into three portions;—the first situated horizontally beneath the liver: the second descending vertically in front of the right kidney; and the third in the transverse meso-colon.

Its mucous membrane presents a number of circular folds, very near each other, which have been called *valvulæ conniventes*. By some anatomists, however, this name is not given to the irregular rugæ of its mucous coat; but to the folds of the lining membrane of the jejunum. The valvulæ are not simple rugæ, passively formed by the contraction of the muscular coat. They are dependent upon the original formation of the mucous membrane; and are not effaced, whatever may be the distention of the intestine.

On and between these duplicatures, the different exhalant and absorbent vessels are situated, forming, in part, the *villi* of the intestine. These villi give to the membrane a velvety appearance, and are not simply composed of exhalants and absorbents, but of nerves; all of which are distributed on a cellular and perhaps on an erectile tissue. The most obvious use of these villi, as Dr. Roget and Dr. Horner have suggested, is to increase the surface from which the secretion is prepared. Within the membrane are numerous follicles, which, with the exhalants, secrete a mucous fluid, called by Haller *succus intestinalis.* Their entire number in the whole alimentary canal is estimated by Dr. Horner to be 46.896.000.

At about four or five fingers' breadth from the pylorus, the duodenum is perforated by the termination of the biliary and pancreatic ducts, which pour the bile and pancreatic fluids into it. Generally, these ducts enter the intestine by one opening; at times, they are distinct, and lie alongside each other.

The structure of the duodenum is the same as that of the whole of the intestinal canal. The muscular coat is, however, thicker, and the peritoneal coat only covers its first portion, passes before the second, and is totally wanting in the third, which we have described as included in the transverse meso-colon.

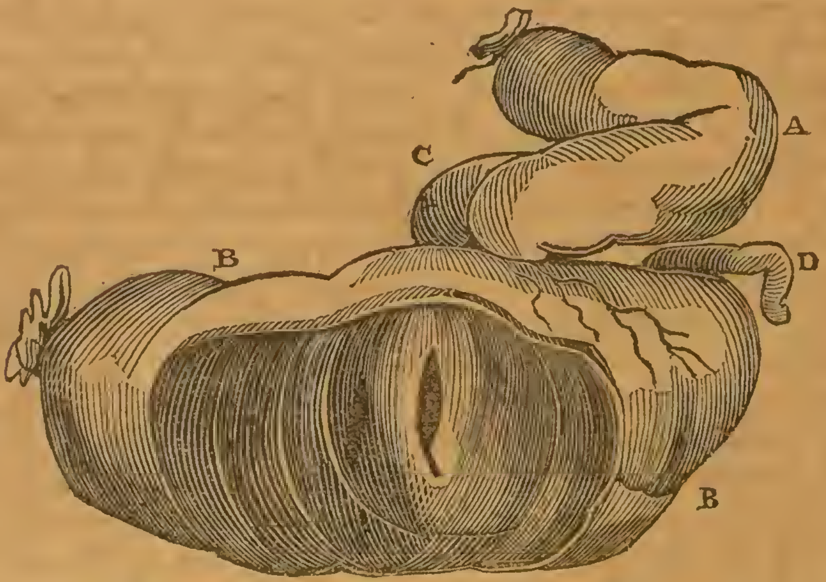
The other two portions of the small intestine are of considerable length; the *jejunum* commencing at the duodenum, and the *ileum* terminating, in the right iliac fossa, in the first of the great intestines—the cæcum. They occupy the middle and almost the whole of the abdomen, being surrounded by the great intestine E F F F G H I, Fig. 103. The jejunum is so called, from being generally found empty; and the ileum, from its numerous windings. The line of demarcation, however, between the duodenum and jejunum, as well as between the latter and the ileum, is not fixed: it is an arbitrary division. The jejunum has, internally, the greatest number of valvulæ conniventes and villi. The ileum is the lowest portion. It is of a paler colour, and has fewer valvulæ conniventes. The jejunum is situated at the upper part of the umbilical region; the ileum at the lower part of it, extending as far as the hypogastric and iliac regions. The mucous membrane of the jejunum and ileum resembles, in essential respects, that of the duodenum; the valvulæ conniventes are, however, more numerous in the jejunum than in the duodenum; and, in the course of the ileum, they gradually disappear, and are replaced by simple longitudinal rugæ. The villi, too, which are chiefly destined for chylous absorption, abound in the jejunum, but gradually disappear in the ileum. The mucous membrane of both is largely supplied with follicles, called the glands of Peyer, Brunner, and Lieberkühn, which secrete the *succus intestinalis,*—a mucous fluid, to which Haller attached unnecessary importance in digestion. Lelut estimates the number of these glands, in the small intestine, at 40.000. The muscular coat is composed of circular and longitudinal fibres; and the outer coat is formed by the prolongation of the peritoneum, which, after having surrounded the intestines, completes the mesentery, by which the gut floats, as it were, in the abdominal cavity.

The *large intestine* terminates the intestinal canal. It is much shorter than the small, and considerably more capacious, being manifestly intended, in part, as a reservoir. It is less loose in the abdominal cavity than the portion of the tube which we have described. It commences at the right iliac fossa, (Fig. 103, E,) ascends along the right flank, as far as the under surface of the liver; crosses over the abdomen to gain the left flank, along which it descends into the left iliac region, and thence through the pelvis, along the hollow of the sacrum, to terminate at the *anus*.

Like the small intestine it is divided into three portions; the *cæcum*, the *colon*, and the *rectum*.

The *cæcum* or *blind gut* is the part of the great intestine into which the ileum opens. It is about four fingers' breadth in length, and nearly double the diameter of the small intestine. It occupies the right iliac fossa, in which it is bound down, so as not to be able to change its position. The extremity of the ileum joins the cæcum, at an angle; and if we examine the interior of the cæcum, at the point of junction, we find a valvular arrangement, which has been called the *valve* of *Tulpius*, *valve* of *Bauhin*, *ileo cæcal valve*, &c.

Fig. 104.



Commencement of the large Intestines.—Valve of Tulpius.

A. C. Small intestine.—B B. Large intestine.—D. Appendix vermiformis cæci.

Fig. 104 exhibits the nature of this arrangement. At the point of union of the two intestines, a soft eminence exists, flattened from above to below, and elliptical transversely, which is divided into two lips. One of these seems to belong to the ileum and colon—hence called *ileo-colic;* the other to the ileum and cæcum, and termed, *ileo-cæcal*.

From the disposition of these lips a valve results, so constituted, that the lips, which form it, separate when the fæcal matters press from the small to the large intestine; whilst they approximate, cross, and completely prevent all retrogression, when the fæces tend to pass from the great intestine to the small. At the extremities of this valve are small tendons, which give it strength, and have been termed the *fræna* or *retinacula of the valve of Bauhin.*

Although this valvular arrangement prevents the ready return of the excrementitious matter into the small intestine, we have many opportunities, in pathology, for discovering, that it is not effectual in all cases. In stricture of the large intestine, stercoraceous vomiting is a frequent concomitant, and there have been instances of substances, thrown into the rectum, having been evacuated by vomiting.

At the posterior and left side of the cæcum, a small process detaches itself, called, from its resemblance to a worm, *appendix vermiformis;* and, from its connexion with the cæcum, *appendix cæci.* It is convoluted, variable in its length, and attached, by its sides, to the cæcum. Its free extremity is impervious; the other opens into the back part of the cæcum.

This appendage to the cæcum has all the characters of an intestine. Various hypotheses have been indulged regarding its uses. Some have conceived it to be a reservoir for the fæces, but its diminutive size, in the human subject, precludes this idea; others have thought, that it secretes a ferment, necessary to fæcal formation; and others, again, a mucus for preventing the induration, which might result from the detention of the fæces in the cæcum. The opinion—that it is a mere *vestige* of the useful and double cæca, which exist in certain animals—is as philosophical as any. M. De Blainville, indeed, regards it as the true cæcum, and what is named the cæcum as the commencement of the colon. It is manifestly of but little importance, as it has been found wanting or obliterated in many subjects, and has been extirpated repeatedly with impunity.

The *colon* is by much the longest of the large intestines, (F F F G H, Fig. 103.) It is a continuation of the cæcum, from which it cannot be distinguished; but is considered to commence at the termination of the ileum. From the right iliac fossa, it ascends along the right lumbar region, over the kidney, to which it is connected. It is, in this part, called the *colon dextrum,—ascending,* or *right lumbar colon.* From the kidney it passes forwards and crosses the abdomen in the epigastric and hypochondriac regions, being connected to the duodenum. This portion is called the *great arch of the colon,* or *colon transversum.* The right portion of the great arch is situated under the liver and gall-bladder; and hence is found after death tinged yellow, owing to the transudation of bile. The left portion of the arch is situated under the stomach; and, immediately below it, are the convolutions of the jejunum. In the left hypochondre, the colon turns backward under the spleen, and descends along the left lumbar region, anterior to the kidney to which it is closely connected. This portion is termed the *colon sinistrum, descending* or *left lumbar colon.* In the left iliac region, it forms two convolutions, which have been compared to the Greek ς, or to the Roman s; and hence this part of the intestine has been designated the *sigmoid flexure*, or *Roman* s, or *iliac turn of the colon.* This flexure varies greatly in length in different persons, extending frequently into the hypogastric region, and, in some instances, as far as the cæcum. The colon, through its whole extent, is fixed to the body by the meso-colon.

The coats of the great intestine are the same in number and structure with those of the small, but they are thinner, and not as easily separated by dissection. The mucous membrane is less villous and velvety. The most characteristic difference, however, in the general appearance of the great and small intestines, is the pouched or cellular aspect of the former. These pouches are reservoirs for the excrement, and in them it becomes more indurated, by the absorption of the fluid portions.

In torpor of this part of the intestinal canal, the fæces are, at times, retained so long, that they become hard balls or scybala; and are not unfrequently the occasion of the inflammation of the lining membrane of the large intestine, which constitutes dysentery.

The longitudinal muscular fibres are concentrated into three ligamentous bands or fasciculi, which run the whole length of the intestine. These fasciculi, being shorter than the intestine, pucker it, and are the occasion of the pouched or saccated arrangement. The inner or circular muscular fibres are, like those of the small intestine, uniformly spread over the surface, and stronger than those of the latter. Lastly, in the great intestine, especially in the colon, are numerous processes of the peritoneum containing fat, and hence called *appendiculæ epiploïcæ*, or *appendiculæ pinguedinosæ.* These are seen in greatest abundance in the right and left lumbar portions of the colon.

The *rectum* terminates the intestinal canal, and extends from the termination of the colon to the anus. It commences about the fifth lumbar vertebra, and descends vertically into the pelvis, following the concavities of the sacrum and coccyx; and, consequently, is not straight, as its name would import. At its upper part, there are a few appendiculæ epiploicæ; and a small duplicature of the mesentery, called *meso-rectum*, attaches it to the sacrum. It differs from the other intestines in becoming wider in its progress downwards, and in its parietes being thicker. The lower part of the mucous membrane exhibits several longitudinal folds or rugæ, which have been considered as the effect of the contraction of the circular fibres of the muscular coat. The longitudinal fibres of this last coat have a different arrangement from that which prevails in the other portions of the large intestine. They are distributed over the whole surface, as in the small intestine—or rather, as in the œsophagus—excepting that, at the lower part of the rectum, they are wanting. On the other hand, the circular fibres are more and more marked, as they approach the outlet, and, by circumscribing the margin of the anus, they form the sphincter ani muscle. Immediately within the anus is the widest portion of the rectum; and, in this part, accumulations of indurated fæces sometimes take place in old people to a surprising extent, owing to torpor of the muscular powers, concerned in the expulsion of the fæces.

Lastly, there are a few muscles, which are concerned in the act of expelling the fæces. These require a short reference. 1. The *sphincter ani* or *coccygeo-anal*, which keeps the anus constantly closed, except during defecation. 2. The *levator ani* or *subpubio-coccygeus*, which, with the next muscle, constitutes the floor of the pelvic and abdominal cavities. It restores the anus to its place, when pushed outwards during defecation. 3. The *coccygeus* or *ischio-coccygeus*, which assists the levator ani, in supporting or raising the lower extremity of the rectum; and 4. The *transversus perinei* or *ischio-perineal*, some fibres of which unite both with the bulbo-cavernosi and with the sphincter ani muscles; and, consequently, it is associated slightly with the action of both one and the other.

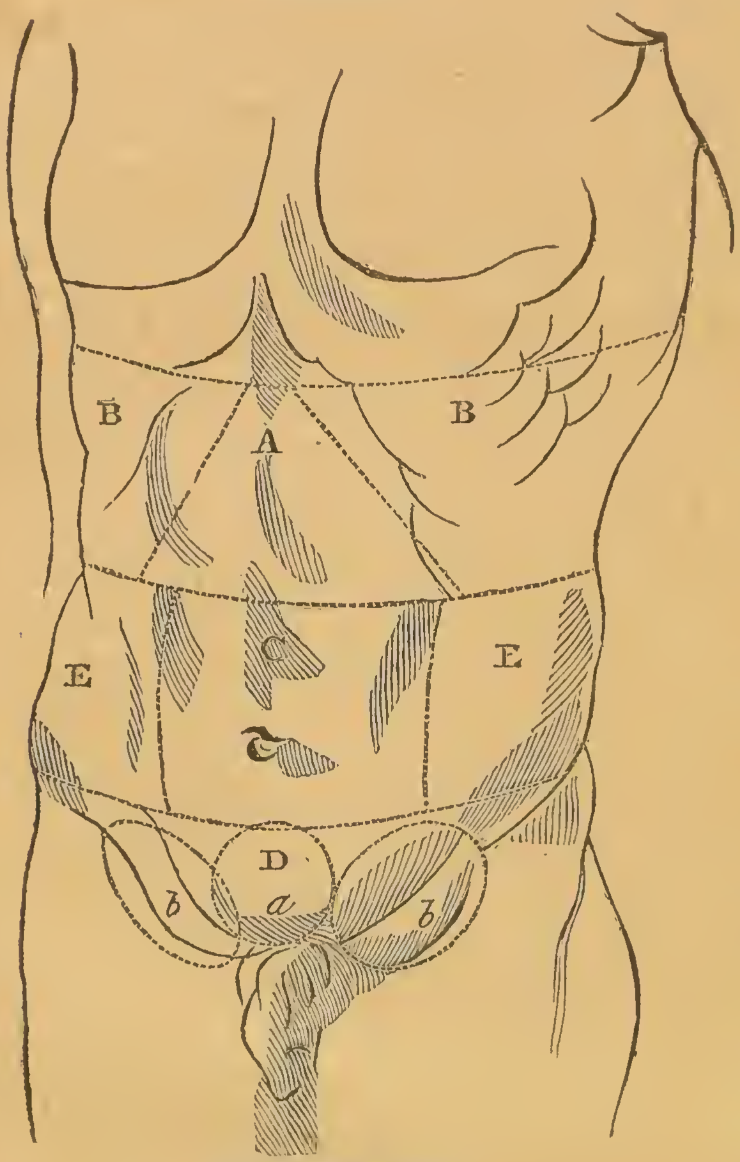
In regard to the intestinal canal, again, we find, that man holds a medium place between the carnivorous and herbivorous animal, although approximating more to the latter. In the carnivorous animal—for reasons more than once mentioned—it is unnecessary, that the food should remain long, and, accordingly, the canal is very short. In the herbivora, on the other hand, and for opposite reasons, the canal is long, and there is generally a large cæcum and a pouched colon. Cuvier has given tables of the length of the canal, compared with that of the *body;* but, where the comparison has been applied to man, the length of the body has included that of the legs. Instead, therefore, of the canal, in man, being considered to bear the proportion of six to one, it ought to be doubled, or as twelve to one; a proportion somewhat greater than prevails in the simiæ or ape tribe. It is not, however, in length always, that the canal of the herbivorous exceeds that of the omnivorous animal; but, as a general rule, it may be affirmed, that the capacity of the canal is much more considerable.

5. The *abdomen*, in which the principal digestive organs are situated, and whose parietes exert considerable influence on the digestive function, will require a brief description. It is that division of the body, which is betwixt the thorax and pelvis; and is bounded, above, by the arch of the diaphragm; behind, by the vertebral column; laterally, and anteriorly, by the abdominal muscles; and, below, by the ossa ilii, os pubis, and by the cavity of the pelvis.

To connect the knowledge of the internal parts of the abdomen with the external, it is customary to mark certain arbitrary divisions on the surface, which have been called *regions*.

The *epigastric region*, A, Fig. 105, is at the upper portion of the abdomen, under the point of the sternum, and in the angle formed by the cartilages of the ribs. The *hypochondriac regions*, B B, are covered by the cartilages of the ribs. These three regions —the epigastric and right and left hypochondre—constitute the upper division of the abdomen, in which are seated the stomach, liver, spleen, pancreas, duodenum, and part of the arch of the colon. The space, surrounding the umbilicus, between the epigastric region and a line drawn from the crest of one os ilii to the other, is the *umbilical region*, C. Here the small intestines are chiefly situated. This region is bounded by lines, raised perpendicularly to the spine of the ilium; and the lateral portions, on the outside of these lines, form the *iliac regions*, E E; behind which, again, are the *lumbar regions*, or the *loins*. In these, the colon and kidneys are chiefly situated.

Fig. 105.



Regions of the abdomen.

The *hypogastric*, D, is, likewise, divided into three regions,—the *pubic* (*a*) in the middle, in which the bladder is situated; and an *inguinal* (*b*) on each side.

The muscles, that constitute the abdominal parietes, are, first of all, above, the diaphragm, which is the boundary between the thorax and abdomen; convex towards the chest, and considerably concave towards the abdominal cavity. Below, if we add the pelvic cavity,—which, as it contains the rectum, and muscles, concerned in the evacuation of the fæces, it may be proper to do,—the cavity is bounded by the perineum, formed chiefly of the levatores ani and coccygei muscles. Behind, laterally, and anteriorly, from the lumbar vertebræ round to the umbilicus, the parietes consist of planes of muscles, and aponeuroses in superposition, and united at the median line, A D, Fig. 105, by a solid, aponeurotic band, extending from the cartilago ensiformis of the sternum to the pubis, called the *linea alba.* The *abdominal muscles*, properly so called, are,—reckoning the planes from within to without,—the greater *oblique muscle*, the *lesser oblique*, and the *transversalis*, which are situated chiefly at the sides of the abdomen;—and the *rectus* and *pyramadalis*, which occupy the anterior part. The *greater oblique*, *obliquus externus* or *costo-abdominalis*;—the *lesser oblique*, *obliquus internus* or *ilio-abdominalis*, and the *transversalis*, *transversus abdominis* or *lumbo-abdominalis*, support and compress the abdominal viscera; assist in the evacuation of the fæces and urine, and in the expulsion of the fœtus; besides other uses, connected with respiration and the attitudes. The *rectus*, *pubio-sternalis* or *sterno pubialis*; and the *pyramidalis* or *pubio-sub-umbilicalis*, are more limited in their action, and compress the forepart of the abdomen; besides having other functions.

Lastly, a serous membrane—the *peritoneum*—lines the abdomen, and gives a coat to most of the viscera. The mode, in which its various reflections are made, is singular, but easily intelligible from the accompanying figure. It has neither beginning nor end, constituting a shut sac, and, in reality, having no viscus within it. If we assume the diaphragm as the part at which it commences, we find it continued from the surface of that muscle over the abdominal muscles, D; then reflected, as exhibited by the dotted line, over the bladder, E; and, in the female, over the uterus, G; from thence over the rectum, F; the kidney, H; enveloping the intestine, B, and constituting, by its two laminæ, the mesentery, C; giving a coat to the liver, A; and receiving the stomach between its duplicatures.

Fig. 106.

Reflections of the peritoneum.

The use of this membrane is to fix and support the different viscera; to constitute, for each, a pedicle, along which the vessels and nerves may reach the intestine; and to secrete a fluid, which enables them to move readily upon each other. When we speak of the cavity of the peritoneum, we mean the inside of the sac; and when it is distended with fluid, as in ascites, the fluid is contained between the peritoneum lining the abdominal muscles, and that which forms the outer coat of the intestines.

The *omenta* or *epiploa* are fatty membranes, which hang over the face of the bowels, and are reflections, formed by the peritoneum after it has covered the stomach and intestines. Their names will sufficiently indicate their situation:—the *lesser epiploon* or *omentum*,—the *omentum hepato-gastricum*; the *greater* or *gastro-colic*; and the *appendices* or *appendiculæ epiploicæ*, which last have already been referred to, and may be regarded as so many small epiploons.

The abdomen is entirely filled by the contained viscera. There are several apertures into it; three, above, in the diaphragm, for the passage of the œsophagus, vena cava inferior, and aorta; one anteriorly in the course of the linea alba, but which is closed after birth,—the *umbilicus;* and two anteriorly and inferiorly; the one—the *abdominal*, *inguinal* or *supra-pubian ring*—which gives passage to the vessels, nerves, &c. of the testicle; and the other—the *crural arch*—through which the vessels and nerves pass to the lower extremity. Lastly, two others exist in the inferior paries, for the passage of the obturator vessels and nerves, and of the sciatic arteries and nerves, respectively.

Such is a brief view of the various organs concerned in digestion. To this might have been added the general anatomy of the liver and pancreas,—each of which organs furnishes a fluid, which is a material agent in the digestive process,—and of the spleen, which has been looked upon by some as inservient, in some manner, to the same function. As, however, the function of these organs will be considered in another place, we defer their anatomy for the present.

Of the Food of Man.

The articles, inservient to the nourishment of man, have usually been considered to belong entirely to the animal and the vegetable kingdoms; but there seems to be no sufficient reason for excluding those articles of the mineral kingdom that are necessary for the due constitution of the different parts of the body. Generally, the term *food* or *aliment*, is applied to substances, which, when received into the digestive organs, are capable of being converted into chyle; but, from this class again, the products of the mineral kingdom cannot, with entire propriety, be excluded.

Animals are often characterized by the kind of food on which they subsist. The *carnivorous* feed on flesh; the *piscivorous* on fish; the *insectivorous* on insects; the *phytivorous* on vegetables; the *granivorous* on seeds; the *frugivorous* on the fruits; the *graminivorous* and *herbivorous* on the grasses; and the *omnivorous* on the products of both the animal and vegetable kingdoms.

In antiquity, we find whole tribes designated according to the aliment they chiefly used. Thus, there were the Æthiopian and Asiatic *Icthyophagi* or fish-eaters; the *hylophagi*, who fed on the young shoots of certain trees; the *elephantophagi*, and *struthiophagi*, the elephant and ostrich eaters, &c. &c.

We have already shown, that the digestive apparatus of man is intermediate between that of the carnivorous and the herbivorous animal; that it partakes of both, and that man may, consequently, be regarded *omnivorous;* that is, capable of subsisting on both the products of the animal and vegetable kingdoms;—an important capability, seeing, that he is destined to live in arctic regions, in which vegetable food is not to be met with, as well as in the torrid zone, which is more favourable for vegetable, than for animal, life.

The nature of the country must, to a great extent, regulate the food of its inhabitants, for although commerce can furnish us with articles of luxury; and with many, which are looked upon as necessaries, no nation is entirely indebted to it for its supplies; besides, numerous extensive tribes of the human family are denied the advantages of commerce, and compelled to subsist on their own resources. This is the great cause, why the Esquimaux, the Samoiedes, &c. live wholly on animal food; and why the cocoanut, the plantain, the banana, the sago, the yam, the cassava, the maize and the millet, form the chief articles of diet with the natives of torrid regions.

In certain countries, the scanty supply of the useful and edible animals has given occasion to certain prohibitory dietetic rules and regulations, which have been made to form a part of the religious creed, and, of course, are most scrupulously observed. Thus, in Hindusthan, animal food is not permitted to be eaten; but the milk of the cow is excepted. Accordingly, to ensure the necessary supply of this fluid, the cow is made sacred; and its destruction a crime against religion. Amongst the laws of the Egyptians are similar edicts, but they seem to have been chiefly enacted for political purposes, and not in consequence of the unwholesome character of the interdicted articles.

The same remark applies to many of the dietetic rules of Moses, for the regulation of the tables of the Hebrews. Blood was forbidden, in consequence, probably, of the fear entertained, that it might render the people too familiar with that fluid, and diminish the horror, which was inculcated against the shedding of blood: the parts of generation were excluded from the table, because the taste might interfere with the reproduction of the species, if it should become indulged, &c. &c.

We have said, that, in the arrangement of his digestive organs, man is intermediate between the carnivorous, and herbivorous, animal. Not the slightest ground is afforded, by anatomy, for the opinion of Rousseau, that man was, originally, herbivorous; or for that of Helvetius, that he was exclusively carnivorous. Broussonet affirms, that he is more herbivorous than carnivorous; since, of his thirty-two teeth, twenty resemble those of the herbivorous, whilst twelve only resemble those of the carnivorous, animal. Accordingly, he infers, that, in the origin of society, his diet must have been exclusively vegetable. Mr. Lawrence, too, concludes, that, whether we consider the teeth and jaws, or the immediate instruments of digestion, the human structure closely resembles that of the simiæ,—the great archetypes, according, to Lord Monboddo and Rousseau of the human race—all of which are, in their natural state, completely herbivorous.

Again, we observe a wide descrepancy between man and animals in the variety of their aliments. Whilst the latter are generally restricted to either the animal or the vegetable kingdom; and to but a small part of one or the other, man embraces an extensive range, and, by means of his culinary inventions, can convert a variety of articles from both kingdoms into materials of sustenance. But, it has been argued by those, who are sticklers for the *natural*, that man probably confined himself, primitively, like animals to one kind of food; that he adhered to this whilst he remained in his *natural state*, and that his omnivorous practices are a proof of his degeneracy. Independently, however, of all arguments deduced from organization, experience sufficiently shows the inaccuracy of these assertions. If we trace back nations to their state of infancy, we find, that then, as in their more advanced condition, the diet was animal, or vegetable, or both, according to circumstances. Of this fact we have some signal examples, in a part of the globe where the lights of civilization have penetrated to a less extent than in most others; and where the influence of circumstances, that prevailed in ancient periods, has continued, almost unmodified, until the present time. Agatharchides describes the rude tribes, who lived on the coast of the Red Sea, and subsisted on fish, under the name *Ichthyophagi*. Along both banks of the Astaboras, which flows on one side of Meroë, dwelt another nation, who lived on the roots of reeds growing in the neighbouring swamps. These roots they cut to pieces with stones, formed them into a tenacious mass, and dried them in the sun. Close to them were the *Hylophagi*, who lived on the fruits of trees, on vegetables growing in the valleys, &c. To the west of these were the hunting nations, who fed on wild beasts, which they killed with the arrow. There were, also, other tribes, who lived on the flesh of the elephant and the ostrich,—the *elephantophagi* and *struthiophagi*. Besides these, he mentions another and less populous tribe, who fed on locusts, which came in swarms from the southern and unknown districts.

The mode of life, with the tribes described by Agatharchides, does not seem to have varied for the last two thousand years. Although cultivated nations are situated around them, they have made no progress themselves. Hylophagi are still to be met with. The Dobenahs, the most powerful tribe amongst the Shangallas, still live on the elephant; and, farther to the west, dwells a tribe, who subsist, in the summer, on the locust; and, at other seasons, on the crocodile, hippopotamus, and fish.

In the infancy of society, mankind were probably almost wholly carnivorous; as the tribes, least advanced in civilization, still are at the present day. For a time, man, in most situations, may have confined himself to the vegetable banquet prepared for him by his bounteous Maker; but, as population increased, the means of subsistence would be too scattered for him, whilst the crowding together of a number of nutritious vegetables into a small space, and the cultivation of the earth, so as to multiply its produce, would imply the existence of settled habits and institutions which could only arise after society had made some progress. Probably, much before this period, it would have been discovered, that certain of the beasts of the forest, and of birds of the air, and some of the insect tribes, could minister to his wants, and form agreeable and nutritious articles of diet; and thus would arise their adoption as food.

On the coasts of the ocean, animal food was perhaps employed from the period of their first settlement; as well as on the banks of the large streams, which are so common in Asia,—the cradle of mankind. The fish, left upon the land after the periodical inundations of the rivers, or thrown on the sea-coast, ministered to their necessities, without the slightest effort on their part; and, hence, they had but little incentive to mental or corporeal exertion. This is the cause of the abject condition of the ichthyophagous tribes of old; and of their comparatively low state of civilization at the present day.

Again, the savages, in various parts of the globe, live by the chace or the fishery; and must, consequently, be regarded as essentially carnivorous.

It would not, however, be justifiable to regard barbarism as the *natural* state of man: nor is it clear what the different writers on this point of anthropology have meant by the term. The Author of Nature has invested man with certain prerogatives, one of which is the capability of rendering the organized kingdom subservient to his wishes and necessities; and, by the invention of the culinary art, of converting various organized bodies into wholesome and agreeable articles of diet, which thus become as *natural* to him as the restriction to one species of aliment is to the animal.

It has been remarked, that the exclusive or predominant use of animal or of vegetable food, has a manifest effect upon the physical and moral powers. Buffon affirms, that if man were obliged to abstain from flesh in our climates, he could not exist, or propagate his kind. Others, again, have depicted a state of ideal innocence, in the infancy of society, when man lived, as they conceive, entirely on vegetables:—

> "His food the fruits; his drink the crystal well;"

unsolicitous for the future, in consequence of the abundant subsistence spread before him; independent, and always at peace with his fellows, and with the other animals; but he gradually sacrificed his liberty to the bonds of society, and cruelty, with an insatiable appetite for flesh and blood, were the first fruits of a depraved nature. Either immediately or remotely, all the physical and moral evil, by which mankind are afflicted, arose from these carnivorous practices.

In point of fact, however, we find, that the countries, in which mankind are accustomed to be omnivorous, or to unite animal with vegetable food, are those, that are most distinguished for both mental and corporeal endowments. The tribes, which feed altogether on animal food,—as the Laplanders, the Samoiedes, the Esquimaux, &c.—are far inferior, in both these respects, to the European or Europeo-American; and the same may be said, although not to the like extent, of the various tribes in whose diet animal food predominates,—as the Indian inhabitants of our own continent. A similar remark is applicable to those, who live almost exclusively on vegetables, as the Hindoos, millions of whom are kept in subjection by a few Europeans.

Attempts have frequently been made to refer the nutrient properties of all articles of diet to a particular principle of a constant character, and which, alone, of all the elements, is entirely capable of assimilation. Haller conceived this to be jelly;—Cullen thought it to be oily, or saccharine, or what seems to be a combination of the two;—Becker, Stahl, Fordyce, &c. to be mucilage; and Dumas, mucus. Richerand, again, attempts to show, that it is, in all cases, either gummy, mucilaginous, or saccharine; and Hallé, that it is a hydro-carbonous oxide, very analogous to gummi-saccharine matter!

It is probable, that there is no such particular principle as the one contended for; and that, in all cases, the food is resolved into its elements, in the formation of the chyle or reparative fluid, separated from it. To this conclusion we are necessarily impelled, when we reflect that the chyle can be formed from both animal and vegetable substances; in other words, that, when vegetable substances are received into the digestive apparatus, they are capable of being converted into a substance, resembling the animal they have to nourish; and, on the other hand, the vegetable has the power of reconverting this animal matter into a substance of its own nature; and hence the utility of manure in promoting vegetation. In an early part of this work, we had occasion to mention, that animals and vegetables are reducible into nearly the same ultimate elements, —in some cases into precisely the same,—oxygen, hydrogen, carbon and azote; the latter being wanting, however, in most vegetables and in several animal substances; and all organized bodies probably possess the power of reducing substances, received as food, into their elements; and of recomposing them, by virtue of affinities which are controlled by the vital agency.

As the different parts of the animal body contain a considerable portion of azote, a question has arisen regarding its source; some believing that it is obtained from the food, others by respiration. The latter adduce the case of the herbivorous animal, which subsists exclusively on substances containing no azote; of nations, which live almost wholly on vegetable food; of the negroes, in the West India Islands, who live almost entirely on the juice of the sugar cane at particular seasons, and yet are unusually healthy and thriving at those seasons: and of caravans journeying across the African deserts, and possessing no other article of diet, for weeks, than gum Arabic or gum Senegal. If we admit, from these and other cases, that man can exist without food containing azote, the origin of the azote of the body must be looked for elsewhere than in the food. Magendie, however, has properly remarked, that they do not lead legitimately to this conclusion. Almost all the vegetables, eaten by man and animals, contain, in reality, more or less azote. The raw sugar, used by the negroes, has a considerable quantity; and with regard to the tribes, which are said to feed almost exclusively on rice, Indian corn, &c. they are in the habit of drinking milk with it, which is a highly azoted substance.

Magendie instituted some experiments with the view of determining this point. These consisted in feeding animals, for the necessary time, on diet whose chemical composition was rigidly determined. He fed a dog, three years old and in good condition, solely on pure white sugar and distilled water. For seven or eight days the animal appeared to thrive well, was lively, and ate and drank with avidity. In the second week, he began to fall off, although his appetite continued good, and he ate six or eight ounces of sugar in the twenty-four hours. In the third week, he became emaciated, his strength diminished, his gaiety was gone, and his appetite impaired. An ulcer formed on each eye, at the centre of the cornea, which subsequently perforated the cornea, and allowed the humours of the eye to escape. The emaciation went on progressively increasing, as well as the loss of strength; and, although he ate daily three or four ounces of sugar, the debility became so great, that he could neither chew nor swallow, nor execute the slightest movement. He died on the thirty-second day from the commencement of the experiment. On dissection, the fat was found to have entirely disappeared; the muscles were reduced to less than five-sixths of their ordinary size; the stomach and intestines were much diminished in size, and powerfully contracted; and the gall and urinary bladders were filled with fluids, not proper to them. These were examined by M. Chevreul, who found them to possess almost all the characters of the bile and urine of the herbivorous animal. The urine, in place of being acid, as it is in the carnivora, was sensibly alkaline, and presented no trace of uric acid or of phosphates. The bile contained a considerable proportion of picromel, like that of the ox and the herbivora in general. The excrements contained very little azote, which they usually exhibit in abundance.

A second dog was subjected to the like regimen, and with similar results. He died on the thirty-fourth day of the experiment.

A third experiment, having afforded analogous results, Magendie concluded, that sugar alone is incapable of nourishing the dog.

In all these cases, ulceration of the cornea occurred, but not exactly at the same period of the experiment.

He next endeavoured to discover, whether these effects might not be peculiar to sugar; or whether the non-azoted substances, generally considered nutritious, might not produce like effects. He took two young and vigorous dogs, and fed them on olive oil and distilled water. For fifteen days they were apparently well; but, after this, the same train of phenomena occurred as in the other cases, except that there was no ulceration of the cornea. They died about the thirty-sixth day of the experiment.

Similar experiments were made with gum Arabic, and with butter—one of the animal substances, which does not contain azote. The results were identical.

Although the character of the excrements, passed by the different animals, indicated that the substances were well digested, Magendie was desirous of establishing this in a positive manner. Accordingly, after having fed animals for several days on oil, gum, or sugar, he opened them, and found that each of these substances was reduced into a particular kind of chyme in the stomach; and that they afforded an abundant supply of chyle;—that from the oil being of a manifest, milky appearance, and that from gum or sugar transparent, opaline, and more aqueous than the chyle from oil; facts which proved, that if the various substances did not nourish the animals, the circumstance could not be attributed to their not having been digested.

These results, Magendie thinks, render it likely, that the azote, found in different parts of the animal economy, is originally obtained from the food taken in. This is, however, extremely doubtful. We have no proof, that the animals died simply from privation of azote. It is, indeed, probable, that the azote had no agency in the matter; for there seems to be no reason why it should not have been obtained from the air in respiration, as well as from that contained between the particles of the sugar, where this substance was administered. It must be recollected, moreover, that the subjects of these experiments were dogs;—animals which, in their natural state, are carnivorous, and, in a domestic state, omnivorous; and that they were restricted to a diet entirely foreign to their nature, and to which they had not been exclusively accustomed. Ought we, under such circumstances, to be surprised that they should sicken and fall off?

Between the period of the publication of the first and the second edition of his *Précis Elémentaire de Physiologie*, Magendie found that his deductions were not, perhaps, as absolute or demonstrative as he had at first imagined; and additional experiments induced him to conclude,—as Dr. Bostock and Sir Charles Bell have since done, without being aware, apparently, of Magendie's observation,—"that variety and multiplicity of articles of food constitute an important hygienic rule." "This," Magendie adds, "is indicated to us by our instinct, as well as by the changes that wait upon the seasons, as regards the nature and kind of alimentary substances."

The additional facts, detailed by Magendie, are the following:—A dog, fed at discretion on pure wheaten bread, and drinking common water, does not live beyond fifty days; whilst another, fed exclusively on military bread,—*pain de munition*,—seems, in no respect, to suffer. Rabbits or Guinea-pigs, fed on a single substance, as on wheat, oats, barley, cabbage, carrots, &c. commonly die, with every mark of inanition, in a fortnight; and, at times, much earlier. When these same substances are given together, or in succession, at short intervals, the animals continue in good keeping. An ass, fed upon rice, lived only fifteen days, refusing his food for the few last days; whilst a cock was fed upon boiled rice for several months, without his health suffering. Dogs, fed exclusively on cheese, and others on hard eggs, lived for a long time; but they were feeble and lean, losing their hair, and their whole appearance indicating imperfect nutrition. The substance, which, when given alone, appeared to support the rodentia* for the greatest length of time, was muscular flesh.

Lastly, Magendie found, that if an animal has subsisted for a certain time on a substance, which, when taken alone, is incapable of nourishing him,—on white bread, for instance,—for forty days,—it is useless, at the end of that time, to vary his nourishment, and restore him to his accustomed regimen. He will feed greedily on the new food presented to him; but will continue to fall off; and will die at the same period as he would probably have done, if maintained on his exclusive regimen.

Independently of showing the necessity of variety of food for animal sustenance, these experiments exhibit some singular anomalies, and sufficiently demonstrate, that we have yet much to learn on the subject. A great deal, doubtless, depends on the habits of the particular animal or individual; and on the morbid effects excited by completely modifying the function of assimilation, as it has been ordinarily practised. It has been long known, that if man, previously habituated to both animal and vegetable diet, be restricted exclusively to one or the other, he will fall off, and become scorbutic; and yet, that he is capable of subsisting upon either one or the other exclusively, provided he be restricted to it from early infancy,

* The *rodentia* are gnawing animals, having large incisors in each jaw, with which they divide hard substances. They are the *rongeurs* of the French naturalists. The squirrel, mouse, rat, Guinea-pig, hare, rabbit, beaver, kangaroo, porcupine, &c. belong to this division.

has been sufficiently shown by the reference already made to carnivorous and herbivorous tribes existing in different regions of our globe. The importance of variety of diet is illustrated by the experiments, which Dr. Stark, of Vienna, made upon his own digestive powers, and to which he ultimately became a martyr. His object was to discover the relative effect of various simple substances, when used exclusively as articles of food for a long space of time. In all such cases, he found that the system was reduced to a state of extreme debility, and that there was not a single aliment, that is capable, of itself, of sustaining the vigour of the body for any considerable period. By this kind of regimen, Dr. Stark is said to have so completely ruined his own health, as to bring on premature death.

The alimentary substances employed by man, have generally been classed, either according to the ultimate chemical elements entering into their composition; or to the chief proximate principle or compound of organization. In the former case, they have been grouped into;—1, those which contain azote, carbon, hydrogen, and oxygen; 2, those which contain carbon, hydrogen, and oxygen; and, 3, those which contain neither azote nor carbon. The first class, it is obvious, will comprise most animal substances. The second chiefly vegetable substances; whilst water is perhaps the only real alimentary matter, that belongs to the third.

The division proposed by Magendie, and adopted by Dr. Paris, is according to the proximate principles, which predominate in the aliment.

1. *Amylaceous aliments;* wheat, barley, oats, rice, rye, Indian corn, potato, sago, salep, peas, haricots, lentils, &c.

2. *Mucilaginous aliments;* carrot, salsify, beet, turnip, asparagus, cabbage, lettuce, artichoke, melon, &c.

3. *Saccharine aliments;* the different kinds of sugar, figs, dates, raisins, &c.

4. *Acidulous aliments;* the orange, currant, cherry, peach, raspberry, strawberry, mulberry, grapes, prunes, pears, apples, tomatos, &c.

5. *Oily and fatty;* cocoa, olives, sweet almonds, hazelnuts, walnuts, animal fats, oils, butter, &c.

6. *Caseous aliments;* the different species of milk, cheese, &c.

7. *Gelatinous aliments;* the tendons, aponeuroses, skin, cellular tissue, the flesh of very young animals, &c.

8. *Albuminous aliments;* the brain, nerves, eggs, &c.

9. *Fibrinous aliments;* comprehending the flesh and blood of different animals.

To these proximate principles, may be added *gluten*, which is the only vegetable compound of organization that contains a notable portion of azote in its composition. Hence its elements most nearly resemble those of the animal kingdom, and it has been termed the most animalized of the vegetable principles. According to Prout, it is separable into two portions, analogous to gelatine and albumen. It is very generally met with, though only in a small proportion, in the vegetable kingdom:—in all the farinaceous seeds, in the leaves of the cabbage, cress, &c.; in certain fruits, flowers, and roots, and in the green fecula of vegetables in general; but it is especially abundant in wheat, and imparts to wheat flour the property of fermenting and making bread. Of the nutritious properties of gluten, distinct from other principles, we know nothing precise: the superior nutritious powers of wheat flour over those of all other farinaceous substances, sufficiently attest, that, in combination with starch, it is highly nutritive.

The different drinks may, like the solid food, be classed according to their chemical character:—1. *Water* of different kinds. 2. *Vegetable and animal juices and infusions*, as lemon-juice, orange-juice, whey, tea, coffee, &c. 3. *Fermented liquors*, as wines, beer, cider, perry, &c.: and 4. *Alcoholic liquors*, as brandy, alcohol, kirschwasser, rum, gin, whisky, arrack, &c. &c.

An inquiry into the different properties of these various liquids does not belong to the physiologist. We may remark, however, that the arguments, regarding the *natural*, have been extended to this variety of aliments; and it has been contended, that water is the most natural drink; and that all others, which are the products of art, ought to be avoided. The remarks, we have already made on this subject, will be sufficient. Water was, doubtless, at one period, the only beverage of man; as nakedness and the use of raw aliment, and the most profound ignorance of the universe was his original condition; but no one will be presumptuous enough to declare, that he ought to continue naked, abjure cookery, and be plunged in his primitive darkness, on the plea that all these changes are so many artificial sophistications.

Water is, doubtless, sufficient for all his wants; but the moderate use of fermented liquors, even if habitual, except in particular constitutions, is devoid, we think, of every noxious result. They are grateful; and many of them are even directly nutritious, from the undecomposed sugar and mucilage which they contain. Dr. Kitchener has, for this reason, termed beer, not inaptly, "liquid bread." With regard to distilled spirits, no evil would result from their total rejection from the table. Although they may, by their action on the digestive organs, be the indirect means of nutrition, they themselves contain no alimentary property. They are received into the vessels of the stomach by imbibition; and always produce, when taken even to a small amount, undue stimulation. This may be productive of little or no mischief, provided they are only used occasionally; but, if taken habitually, serious visceral and mental disorder may sooner or later ensue.

Lastly. There are certain substances, called *condiments*, employed in diet, not simply because they are nutritive,—for many of them possess no such properties,—but because, when taken with food capable of nourishing the frame, they promote its digestion, correct some injurious property it possesses, or add to its sapidity. Dr. Paris has divided these into the *saline*, the *spicy* or *aromatic*, and the *oily*. It may be remarked, however, that certain articles are called, at times, *aliments*, at others, *condiments*, according as they may constitute the basis or the accessory to any dish;—such are cream, butter, mushrooms, olives, &c. The advantage of condiments to animal digestion is strongly exemplified by many cases. The bitter principle, which exists in grasses and other plants, appears to be essential to the digestion of the herbivora;—acting as a natural stimulant; and it has been found, that cattle do not thrive upon grasses, which are destitute of the principle. Of the value of salt to the digestive function of his cattle, the agriculturist has ample experience; and the salt licks of our own country demonstrate how grateful this natural stimulant is to the beasts of the forest. Charcoal, administered with fat,—as it is done, in rural economy for fattening poultry, in many parts of England,—strikingly exhibits the advantage of administering a condiment: it is a substance which of itself contains no nourishment, but can put the digestive function into a condition for separating more nutritious matter from the food taken in, than it could otherwise accomplish. A similar effect is produced by the plan,—adopted for the same purpose in some parts of Great Britain,—of giving walnuts, coarsely bruised, with the shell, and cramming the animal with this diet. This is asserted, by many rural economists, to be the most effectual plan for fattening poultry speedily; the coarse shell, in passing along the mucous membrane of the chylopoietic organs, stimulates it to augmented action; and a more bountiful separation of nutritious matter or of chyle is the consequence. The aromatic condiments act in a similar manner.

These few remarks on the food of man will introduce us to the mode in which the various digestive processes are accomplished. The more intimate consideration of alimentary substances, with their comparative digestibility, &c., will be found in another work, to which the reader is referred.*

Physiology of Digestion.

The detail entered into regarding the various organs concerned in digestion, will have induced the anticipation, that the history of the function must be multiple and complex. The food is not, in the case of the animal—as it is in that of the vegetable—placed in immediate contact with the being to be nourished; consequently an act of volition is necessary to procure it, and to convey it to the upper orifice of the digestive tube. This act of volition is excited

* On the influence of atmosphere and locality; change of air and climate; seasons; food; clothing; bathing; exercise; sleep; corporeal and intellectual pursuits, &c. &c. on human health; constituting Elements of Hygiène. By Robley Dunglison, M. D. p. 205. Philadelphia, 1835.

by an internal sensation—that of hunger—which indicates to the animal the necessity for taking fresh nourishment into the system. The appetite and hunger, with the prehension or reception of food, must therefore be regarded parts of the digestive operations. These may be enumerated and investigated in the following order:—1st. *Hunger*, or the sensation, which excites us to take food. 2d. *Prehension of food*, the voluntary muscular action, which introduces it into the mouth. 3d. *Oral* or *buccal digestion*, comprising the changes wrought on the food in the mouth. 4th. *Deglutition*, or the part taken by the pharynx and œsophagus in digestion. 5th. *Chymification*, or the action of the stomach on the food. 6th. The *action of the small intestine*. 7th. The *action of the large intestine*. And 8th. *Defecation* or *the expulsion of the fæces*. All these processes are not equally concerned in the formation of chyle. It is separated in the small intestine: the first six consequently belong to it;—the remainder relate only to the excrementitious part of the food. The digestion of solid food requires all the eight processes. That of liquids is more simple; comprising only thirst, prehension, deglutition, the action of the stomach, and that of the small intestine. The fluid rarely reaches the large intestine.

In inquiring into this important and interesting function, we shall first attend to the digestion of solids, and afterwards to that of liquids.

I. *Digestion of solid Food.*

1. *Hunger.*—Hunger is really an internal sensation, the seat of which is invariably referred to the stomach. Like every internal sensation, it proceeds from changes in the very texture of the organ. It is not produced by any external cause; and to it are applicable all those observations, which were made on the internal sensations in general.

In its slightest condition, it is merely an *appetite;* but if this be not heeded, the painful sensation of hunger supervenes, which becomes more and more acute and lacerating, unless food be taken. If this be the case, however, the uneasiness gradually abates; and if additional food be taken, a feeling of satiety is produced.

The sensation usually occurs, in the healthy state, after the stomach has been for some time empty, having finished the digestion of the substances taken in at the previous meal. Habit has a great effect in regulating this recurrence; the appetite always appearing about the time at which the stomach has been accustomed to receive food. This artificial desire may be checked by various causes;—by the exciting or depressing passions, by the sight of a disgusting object, or anything that excites intense mental emotion; or it may be appeased by filling the stomach with substances that contain no nutritious properties. As, however, the feeling of true hunger arises from the wants of the system, the natural and instinctive sensation soon appears, and cannot be long postponed by any of these means. Hence, it has been proposed to make a distinction between the *appetite* and *hunger;* applying the former term to the artificial, the latter to the natural, desire. In these respects, there is certainly a wide distinction between them, as well as in the capriciousness, which occasionally characterizes the former, and gives rise to the most singular and fantastic preferences.

The sensation of hunger varies in intensity according to different circumstances. It is more powerful in the child and the youth, than it is in the adult, who has attained his full height. In the period of second childhood, it is urgent, probably owing to the diminished power of assimilation requiring, that more aliment should be received into the stomach. In the state of disease, the sensation is generally suppressed, and its place is often supplied by loathing or disgust for food: at times, again, its intensity makes it a true disease, as in bulimia, and in pica; in the latter of which, the appetite is, at times, irresistibly directed to substances, which the person never before relished, or which are not edible,—as chalk, earth, slate pencil, &c.

The appetite is, also, modified by the degree of exercise or inactivity, to which the individual has been subjected;—regular exercise, and the exhilarating passions; a cold and dry atmosphere, &c. augmenting it, whilst it is blunted by opposite circumstances.

Long-continued exertion, with a scanty supply of nourishment, if not continued so long as to injure the tone of the stomach, produces, occasionally, in adults, a voracious appetite and rapid digestion. Mr. Hunter has quoted, in illustration of this point, the following extract from Admiral Byron's narrative. After describing the privations he had suffered, when shipwrecked on the coast of South America, the admiral incidentally refers to their effect upon his appetite. "The governor," he says, "ordered a table to be spread for us with cold ham and fowls, which only we three sat down to, and in a short time despatched more than ten men with common appetites would have done. It is amazing, that our eating to that excess we had done from the time we first came among these kind Indians had not killed us, as we were never satisfied, and used to take all opportunities for some months after, of filling our pockets, when we were not seen, that we might get up two or three times in the night to cram ourselves."

Authors have distinguished, in hunger, the local from the general phenomena; but many of their assertions on these points appear to be imaginative. We are told by Adelon and others, that the stomach becomes contracted, and that this change is effected by the sole action of its muscular coat;—the mucous or lining membrane becoming wrinkled, and the peritoneal coat, externally, permitting the organ to retire between its laminæ. Such, MM. Tiedemann and Gmelin assert, is the result, also, of their observations. Magendie, however, affirms, that after twenty-four, forty-eight, and even sixty hours of complete abstinence, he has never witnessed this contraction of the stomach. The organ had always considerable dimensions, especially in its splenic portion. It was not until after the fourth or fifth day, that it appeared to him to close upon itself, to diminish greatly in capacity, and to change its position slightly; and these effects were not observed unless the fasting was rigorously maintained.

At the same time, that the stomach changes its shape and situation, the duodenum is said to be drawn slightly towards it; its parietes to appear thicker,—and the mucous follicles and nervous papillæ to project more into its interior. Its cavity is void of food, and contains only a little saliva, mixed with bubbles of air, a small quantity of mucus and, according to some, a little bile and pancreatic juice, which the traction of the duodenum has caused to flow into it. Much dispute has arisen as to whether the circulation of the blood in the stomach experiences any mutation. Dumas was of opinion, that when the organ is empty, it receives less blood than when full; either on account of the great flexion of the vessels in the former case, or on account of the compression, experienced by the nerves, in consequence of the contracted state of the organ. He thinks that, under such circumstances, a part of the blood, which is distributed to that viscus, reflows into the liver, spleen, and omentum; and he regards these organs as diverticula for the blood of the stomach, especially as the liver and spleen are then less compressed, and the omentum more extensive, owing to the retraction of the stomach.

Bichat denies both the fact and its explanation. He affirms that, on opening animals suffering under hunger, he never observed the vessels of the stomach less full of blood, the mucous membrane less florid, or the vessels of the omentum more turgid. It is not true, he adds, that the vessels of the stomach are more flexuous when the organ is empty: being connected with the serous coat, as well as the nerves, they are unaffected by changes of size in the organ; besides the retraction of the stomach could never be great enough to compress the nerves. He denies, moreover, that the liver and spleen are more free, and the omentum larger, whilst the stomach is empty, as the abdominal parietes contract in the same proportion as the stomach. Magendie, however, contests this last assertion of Bichat. He affirms, on the faith of positive experiments, that the pressure, sustained by the abdominal viscera, is in a ratio with the distention of the stomach. If the stomach be full, the finger introduced into the cavity of the abdomen, through an incision in its parietes, will be strongly pressed upon, and the viscera will be forced towards the opening; whilst, if it be empty, the pressure is inconsiderable, as well as the tendency of the viscera to escape through the opening. During the state of vacuity of the organ, he remarked, that the different reservoirs in the cavity of the abdomen,—as the bladder and gall-bladder,—were more easily filled by their proper fluids. With regard to the quantity of blood circulating through the stomach in the empty and full state;—he is disposed to think, that it receives less in the former condition; but instead of its differing in this respect from the other abdominal viscera, he thinks, that such is the case with every organ in the abdomen.

The *general* effects, said to be produced by hunger, in contradistinction to the *local*, are;—debility and diminished action of every organ. The circulation and respiration slacken; the heat of the body sinks; the secretions diminish, and all the functions are exerted with more difficulty, if we except absorption, which, it is affirmed, and with much probability, is augmented.

If the abstinence be so long protracted as to cause death, the debility of the functions becomes real, and not sympathetic. Respiration and circulation languish; all the animal functions totter; whilst absorption continues, and the blood is supplied by the decomposition of the different organs. The fat, the various liquid matters, other than the blood, the tissues and the organs themselves are successively subjected to its action. It is obvious, however, that, with the constant drain perpetually taking place, this state of affairs cannot long exist; the blood becomes diminished in quantity, and insufficient in every respect to vivify the organs; the functions of the brain are perverted, and, in many instances, we are told, the most furious delirium closes the scene; whilst, at others, the miserable sufferer sinks passively into the sleep of death.

Occasionally, again, so dreadfully painful are the sensations, caused by protracted privation of food, that the most violent antipathies and the dearest affections are overcome; and numerous instances have occurred in which the sufferer has attacked his own species, his friends, his children, and even the substance of his own body. The horrible picture of the shipwreck, in the *Don Juan* of Byron, is not a mere romance. It is but the actual fact, expanded somewhat by the imagination of the poet.

Dr. James Currie has related the case of a person, who died of inanition from stricture of the œsophagus, the particulars of which may exemplify the phenomena, presented by some of those who perish from abstinence. The records of such cases are rare. From the 17th of October to the 6th of December, the patient was supported without the aid of the stomach, by means of broth clysters, and was immersed in a bath of milk and water;—circumstances, which probably modified the symptoms but little, inasmuch as we shall find hereafter, that but little nutritive absorption can be effected through the cuticle. At one period he had a parched mouth; a blister discharged only a thin, coagulable lymph; and the urine was scanty, extremely high-coloured, and intolerably pungent. The heat of the body was natural and nearly uniform, from first to last; and the pulse was perfectly natural until the last days. His sleep was sound and refreshing; his spirits even: and his intellect unimpaired, until the last four days of existence, when the clysters were no longer retained. Vision was deranged on the first of December, and delirium followed on the succeeding day; yet the eye was unusually sensible, and the sense of touch remarkably acute. The surface and extremities were at times of a burning heat; at others, clammy and cold. On the fourth, the pulse became feeble and irregular, and the respiration laborious; and, in ninety-six hours after all means of nutrition as well as all medicine had been abandoned, he ceased to breathe. He was never much troubled by hunger. Thirst was, at first, troublesome, but it was relieved by the tepid bath.—This was one of the cases in which the patient sinks tranquilly to death. In others, the distressing accompaniments, above described, are met with; and the death is that of the furious maniac.

The period at which death will occur from protracted abstinence is dependent on many circumstances. As a general rule it may be assumed, that the young and robust will expire sooner than the older; and this will have to be the guidance in questions of survivorship, that may arise when several individuals have perished together from this cause. The picture, drawn by Dante, of the sufferings and death of Count Ugolino della Gherardescha who saw his sons successively expire before him from hunger, in this respect true to nature:—

> "Now when our fourth sad morning was renew'd,
> Gaddo fell at my feet, outstretch'd and cold
> Crying:—'Wilt thou not, father! give me food?'
> There did he die; and as thine eyes behold
> Me now, so saw I three fall, one by one,
> On the fifth day and sixth: whence in that hold,
> I, now grown blind, over each lifeless son,
> Stretch'd forth mine arms. Three days I call'd their names,
> Then Fast achieved what Grief not yet had done."
>
> *Inferno*, Canto XXXIII.

The sensation of hunger resembles every other internal sensation in the mode in which it is accomplished. There must be impression, conduction, and perception. That the brain is the organ of the last part of the process is proved by all the arguments used in the case of the internal sensations in general. Without its intervention, in this, as in every other case, no sensation can be accomplished. The stomach is the organ in which the impression is effected; and, by means of the nerves, this impression is conveyed to the encephalon.

The eighth pair, or pneumogastric nerves, have generally been regarded as the agents of this transmission; and it has been affirmed by Baglivi, Valsalva, Haller, Dumas, Legallois, Chaussier, and others, that if these nerves be divided in the neck, although the stomach may be, in other respects, favourably circumstanced for the developement of the impression of hunger, and the brain ready for its reception, there is no sensation. MM. Leuret and Lassaigne, however, deny that such effect follows the division of these nerves; and they affirm, that horses have eaten as usual, and apparently with the same appetite, after they had removed several inches of the pneumogastric nerves; and that they even continued to eat after the stomach was filled. To these experiments we shall have occasion to refer hereafter. They by no means exhibit, that this internal sensation differs from others; and that the three actions are not equally necessary for its accomplishment.

The difficulty, which the physiologist has always felt, regards the precise nature of the action of impression. Its seat is clearly in the stomach. This was incontestably shown, in a case of fistulous opening into the stomach, which fell under the care of Dr. Beaumont, and to which we shall have frequent occasion to refer: when the subject of the case was made to fast until the appetite was urgent, it was immediately assuaged by feeding him through the aperture. To the stomach, all our feelings refer the sensation. It is dependent upon some modification, occurring in the very tissue of the viscus; and in the nerves, which, as has been shown, are the sole agents in all the phenomena of sensibility. These nerves are spread over the stomach, so that the precise seat of the impression cannot be as accurately defined as in the case of the organs of external sense. Moreover, the nerves of the stomach proceed from two essentially different sources,—from the eighth pair, and from the great sympathetic. The question consequently arises,—on which of these is the impression made? The experiment of cutting the eighth pair in the neck would appear to decide in favour of the former.

As to the proximate or efficient cause of hunger, we cannot expect to arrive at any satisfactory conclusion. It is a sensation; and, like all sensations, necessarily inscrutable. Theories, however, as on all obscure topics, have been numerous, and these have generally been of a mechanical or a chemical nature. Some have attributed it to the mechanical friction of the parietes of the stomach against each other, in consequence of the contraction of the organ; in which state, they affirm, the mucous coat is rugose, and its papillæ and follicles prominent. It is manifest, however, from the structure of the organ, that no such friction can possibly take place. Yet this view was embraced by Haller. Others, again, have accounted for the sensation by the action of the gastric juice, which is supposed to have a tendency to corrode the internal membrane. In proof of this, they refer to a case, mentioned by Hunter, in which the mucous membrane, in a man who died of fasting, was found corroded. The gastric juice is, however, incapable of eroding living animal matter; and the numerous cases, which have occurred, since that of Hunter, have sufficiently shown, that the corrosion and perforation, which we meet with on dissection, are to be referred to an action after death, and are, consequently, totally unconnected with the sensation felt during life. We have, indeed, no reason for believing that the gastric juice can ever attain a state of acridity, and act upon the surface, by which it is secreted. It has been already remarked, that it is a law of the animal economy, that no secretion acts upon the part over which it is destined to pass, provided such part be in a healthy condition. Yet Sömmering ascribes the pain, from long-continued fasting, to the action of the gastric juice; and Dr. Wilson Philip is manifestly induced to believe, that the influence of the gastric juice on the stomach is, in some mode or other, productive of the sensation; his remarks, however, tend simply to show,—what we have so many opportunities of observing,—that the sensation can be postponed by exciting vomiting, or by inducing, for the time, a morbid condition of the stomach. The unanswerable objection, however, to all these views is the fact—repeatedly proved by Dr. Beaumont and which the author had an opportunity of observing—that, in the fasting state, there is no gastric juice in the cavity of the stomach. Dr. Beaumont, himself, thinks, that the sensation of hunger is produced by distention of the vessels, which secrete the gastric solvent; but such distention, if it exist—which is by no means proved—must itself be consecutive on the nervous condition, that engenders the sensation; the efficient cause of such conduction has still to be explained.

Bichat, again, attributed it to the lassitude or fatigue of the stomach, occasioned by the contraction of its muscular coat, when prolonged beyond a certain time. In answer to this, it may be remarked, that, if anything impedes the nutrition of the body, hunger still continues, although the stomach may be distended. This happens in cases of scirrhous pylorus, where the nutritive mass cannot pass into the small intestine, to be subjected to the action of the chyliferous vessels, and the losses of the body cannot, therefore, be repaired;—facts which would seem to show, that hunger is a sensation, excited in the stomach by sympathy with the wants of the constitution; and that it is immediately produced by some alteration in the condition of the nerves of the organ, which is inappreciable to us. It appears, from the experiments of Magendie, that when the cerebrum and great part of the cerebellum were removed in ducks, the instinct of seeking food was lost in every instance, and the instinct of deglutition in many: food, however, introduced into the stomach was found to be digested.

2. *Prehension of food.* The arms and the mouth have been described as the organs of prehension. It is scarcely necessary to say, that the hands seize the food and convey it to the mouth under ordinary circumstances; but there are cases in which the mouth is the sole or chief organ of prehension. Most animals are compelled to use the mouth only. When the food is conveyed to the mouth by the hands, it must open to receive it. The mode in which this is effected has given rise to much controversy; and strange to say is not yet considered determined.

Whilst some physiologists have asserted, that the lower jaw alone acts in opening the mouth moderately; others have affirmed, that both the jaws separate a little; the lower, however, moving five or six times as much as the upper. That the latter is the correct view can be proved by positive experiment. If, when the mouth is closed, we place the flat side of the blade of a knife against the teeth of both jaws; and, holding the knife immovably, separate the jaws; we find, that both jaws move on the blade; but the lower to a much greater extent than the upper. Now, as the upper jaw is fixed immovably to the head; the whole head must, of necessity, participate in this movement; and the question arises, what are the agents that produce it? Boerhaave, Monro and Pringle attribute it to a slight action of the extensor muscles of the head; and they affirm, that, whilst the depressors of the lower jaw carry it downwards, the extensors of the head draw the head slightly backwards, and thus raise the upper jaw.

Magendie and Adelon assert, that when the mouth is opened moderately, the upper jaw does not participate; but, that if the motion be "forced" or extensive, the upper jaw participates slightly. The experiment, however, with the knife, which is adduced by Adelon himself, completely overthrows this notion, and shows, that both jaws act, whenever the mouth is slightly opened.

Magendie agrees with Boerhaave, Monro, and Pringle, that, whenever the upper jaw is raised, it must be by the head being thrown back on the vertebral column; and he properly remarks, that where there is a physical impediment to the depression of the lower jaw, the mouth must be opened solely by the retroversion of the head on the spine.

Ferrein conceived, that the motion of the upper jaw is occasioned by the action of the stylo-hyoideus muscle, and of the posterior belly of the digastricus; and he affirms, that whilst the anterior fasciculus or belly of the digastricus depresses the lower jaw; the posterior belly, with the stylo-hyoideus, carries the head backwards, and, with it, the upper jaw. The attachments, however, of these muscles sufficiently show, that they cannot be the agents: the mastoid process, to which the posterior belly of the digastric muscle is attached, is near the articulation of the head with the atlas; whilst the styloid process, to which the stylo-hyoideus is attached, is anterior to the articulation, and its effect ought, therefore, to be to depress the upper jaw.

The view of Professor Chaussier is the most probable. He ascribes the slight elevation of the upper jaw to the mechanical arrangement of the joint of the lower jaw. The temporo-maxillary articulation is not formed by a single condyle, but by two, which are so disposed, that the lower cannot roll downwards during the depression of the lower jaw, without causing the upper condyle to roll upwards, and, consequently, to slightly elevate the upper jaw.

Under ordinary circumstances, then, the jaws cannot be at all separated without both participating; but if we determine to fix the upper jaw we can make the lower the sole agent.

As soon as the food is introduced into the mouth, the jaws are closed to retain it, and subject it to mastication. Frequently, however, they assist in the act of prehension, as when we bite into a fruit, to separate a portion from it;—the incisor teeth acting, in such case, like scissors. This is chiefly produced by the contraction of the muscles, that raise the lower jaw; and it is probable, that the action of the stylo-hyoideus is concerned in this movement;—drawing the head and upper jaw with it downwards and forwards. The levator muscles of the jaw act here with great disadvantage;—the lower jaw representing a lever of the third kind; the fulcrum being in the joint; the power at the insertion of the levator muscles; and the resistance in the substance between the teeth. The arm of the resistance is, consequently, the whole length of the lever; and we can readily understand, why we are capable of developing so much more force, when the resistance is placed between the molares; and why old people,—who have become toothless, and are, consequently, constrained to bite with the anterior part of the jaws,—the only portion, that admits of contact,—cannot bite with any degree of strength.

The size of the body, put between the incisor teeth, influences the degree of force that can be brought to bear upon it. When small, the force can be much greater, as the levator muscles are inserted perpendicularly to the lever to be moved; and the whole of their power is advantageously exerted; but if the body be so large, that it can scarcely be received into the mouth, and be resisting withal, the incisors can scarcely penetrate it;—the insertion of the levator muscles into the jaw being rendered very oblique; and the greater part of the force they develope being consequently lost. This will be readily seen by the illustration, Fig. 107. When the mouth is closed, or nearly so, the masseter and temporal muscles, represented respectively by the lines B E and J *j*, are inserted nearer the perpendicular; but when the lower jaw is depressed, so that the situation of these muscles is represented by the dotted lines B *e* and J *k*, the direction, in which the muscles act, will be much more oblique, and, therefore, more disadvantageous.

Fig. 107.

A. The frontal bone.—B. The temporal.—C. The parietal.—D. The occipital.—E. The coronoid process of the lower jaw, to which the temporal muscle is attached.—F. The condyloid process or head of the lower jaw.—G. The lower jaw.—H. The mastoid process.—I. The upper jaw.—J. The cheek bone.—K. The orbit.—L. The meatus auditorius externus.—L*. The coronal suture.—M. The squamous suture.—N. The lambdoidal suture.—*g*. The lower jaw depressed.

When the muscles of the jaws are incapable, of themselves, of separating the substance, as in the case of the apple, the assistance of the muscles of the hand is invoked; whilst the muscles on the posterior part of the neck, which are inserted into the head, draw it backwards; and, by these combined efforts, the substance is forcibly divided.

3. *Oral or buccal digestion.*—The changes, effected upon the food in the mouth, are important preliminaries to the function, which has to be executed in the stomach and duodenum. As soon as the food enters the cavity, it is subjected to the action of the organ of taste; and its sapid qualities are duly appreciated. By its stay there, it also nearly acquires the temperature of the cavity. This is, however, a change of little moment, unless the food be so hot, that it would injure the stomach, if passed rapidly into it. Under such circumstances, it is tossed about the mouth, until it has parted with its caloric to various portions of the parietes of the cavity; and then, if in a fit state for the action of deglutition, it is

transmitted along the œsophagus; but the most important parts of oral digestion, are the movements of mastication and insalivation; by which the solid food is comminuted, and imbued with the secretions that are poured into the interior of the mouth, and which we have shown to be of a very compound character.

Under the sense of taste, the influence of the agreeable or disagreeable character of the food upon the digestive function was expatiated upon. It is unnecessary, therefore, to do more than allude to the subject here. We find them mutually influencing each other: whilst a luscious aliment excites us to prolonged mastication, and the salivary glands to augmented secretion, the masticatory and salivary organs, by dividing and moistening the food, permit the organs of gustation to enjoy the savour in successive applications.

When the food is received into the mouth, if it be sufficiently soft, it is commonly swallowed immediately; unless the flavour be delicious, when it is detained for some time. If solid, and, especially, if of any size or density, it is divided into separate portions, or is chewed,—the action constituting *mastication.*

If the consistence of the substance be moderate, the tongue, by being pressed strongly against the bony palate, is sufficient to effect this division; bruising it, and, at the same time, expressing its fluid portions. If the consistence be greater, the action of the jaws and teeth is required. For this purpose, the lower jaw is successively depressed and elevated by the action of its depressors and levators; and the horizontal or grinding motion is produced at pleasure by the action of the pterygoid muscles. Whilst these muscles are acting, the tongue and the cheeks are incessantly moving, so as to convey the food between the teeth, and insure its comminution. Mastication is chiefly effected by the molares. There is advantage in using them, independently of their form, in consequence of the arm of the resistance being much shortened, as has already been shown.

The teeth are well adapted for the service they have to perform. The incisors, as their name imports, are used for cutting; hence their coronæ come to an edge; the canine teeth penetrate and lacerate, and their coronæ are acuminated; whilst the molares bruise and grind, and their touching surfaces are tuberous. The first, having usually no great effort to sustain, are placed at the extremity of the lever; the latter, for opposite reasons, are nearest the fulcrum. To preclude displacement, by the efforts they have occasionally to sustain, they are firmly fixed in the alveoli or sockets; and, as the roots are conical, and the alveoli accurately embrace them, the force, as in the case of the wedge, is transmitted in all directions, instead of bearing altogether upon the jaw, which it would do, were the fangs cylindrical. The molar teeth, having the greatest efforts to sustain, are furnished with several roots; or with one, which is extremely large.

The gums add materially to the solidity of the junction of the teeth with the jaw. They are themselves formed of highly resisting materials, so as to withstand the pressure of hard and irregular substances. Whenever they become spongy, and fall away from the teeth, the latter become loose; and are frequently obliged to be extracted, in consequence of the loose tooth acting as an extraneous body, and inflaming the lining membrane of the alveolus. The arrangement of the jaws is likewise well adapted to the function; the lower jaw passing behind the upper at its anterior part; but coming in close contact at the sides, where mastication is chiefly operated.

During the whole time that mastication is going on, the mouth is closed;—anteriorly, by the lips and teeth, which prevent the food from falling out of the cavity; and, posteriorly, by the velum palati, the anterior surface of which is applied to the base of the tongue. At the same time, the food is undergoing admixture with the various fluids poured into the mouth, and particularly with the saliva, the secretion of which is augmented, not only by the presence of food, but even by the sight of it, especially if the food be desirable;—giving rise to what is called "mouth-watering." It is probable, that, independently of the mental association, the action of the secretory organs is increased by the agitation of the organs themselves during the masticatory movements. It has, indeed, been asserted, that the parotid glands are so situated, as regards the jaws, that the movement of the lower jaw presses upon them, and forces out the saliva; but Bordeu and J. Cloquet have demonstrated, both anatomically and by experiment, that such is not the case.

It has been supposed, by some, that the admixture with the saliva communicates to the food its first degree of animalization; or in other words, its first approximation to the substance of the animal it has to nourish. Such are the opinions of Drs. Jackson and Voisin. The former asserts, that he has ascertained positively, that the saliva exerts a very energetic operation on the food, separating, by its solvent properties, some of its constituent principles, and performing a species of digestion. It is more probable, however, that the great use of mastication and insalivation is to give the food the necessary consistence, in order that the stomach and small intestine may exert their action upon it, in the most favourable manner; and that, consequently, the changes effected upon the aliment in the mouth, are chiefly of a mechanical character.

In the case of many substances—as sugar, salt, &c.—a true solution takes place in the saliva; and this probably happens to sapid bodies in general; the particles being separated by imbibing the fluid. Krimer, of Leipzig, held in his mouth a piece of ham, weighing a drachm, for three hours. At the expiration of this time, the ham was white on its surface, and had increased in weight twelve grains. Krimer, it may be remarked, believes, that the tears assist in digestion, and that they flow constantly by the posterior nares into the stomach.

Both mastication and insalivation are of great moment, in order that digestion shall be accomplished in perfection; and, accordingly, we find, that they who swallow the food without due mastication, or waste the saliva by constant and profuse spitting, are more liable to attacks of dyspepsia, or imperfect digestion.

The degree of resistance, and the sapidity of the food, apprize us when mastication and insalivation have been sufficiently exerted. When such is the case, it is subjected to the next of the digestive processes. Some physiologists have affirmed, that the uvula is the organ, which judges when the food is adapted for deglutition. Adelon, whose views are generally worthy of great favour and attention, asserts, "that it judges by its mode of sensibility, of the degree in which the aliment has been prepared in the mouth; of the extent to which it has been chewed, impregnated with saliva, and reduced to paste; and, according to the impression it receives from the aliment, it excites, sympathetically, the action of all those parts; directs the convulsive contraction of the muscles that raise the pharynx, and even keeps the stomach on the alert, and disposes it to receive favourably or to reject the food passing to it."

Such a function would be anomalous. It is, indeed, impossible for us to conceive, how so insignificant an organ could be possessed of these elevated attributes. Observation, also, proves, that the notion is the offspring of fancy. Magendie asserts, that he has known several persons, who had entirely lost the uvula, either by venereal ulceration or by excision, and yet he never remarked that their mastication experienced the slightest modification, or that they swallowed inopportunely. Our experience corresponds with that of Magendie. At this very time, we have, under our eye, an individual in whom there is not the slightest vestige of uvula, yet he tastes, chews, and swallows like other persons.

4. *Deglutition.*—The act of swallowing, although executed with extreme rapidity, and apparently simple, is the most complicated of the digestive operations. It requires the action of the mouth, pharynx, and œsophagus. It has been well analyzed by Magendie,—first of all in a thesis, maintained at the *Ecole de Médecine* of Paris, in 1808, and subsequently, in his *Precis élémentaire de Physiologie.* To facilitate its study, he divides it into three stages. In the *first*, the food passes from the mouth into the pharynx; in the *second*, it clears the apertures of the glottis and nasal fossæ, and attains the œsophagus; and, in the *third*, it clears the œsophagus and enters the stomach.

1. When the food has been sufficiently masticated and imbued with saliva, it is collected by the action of the cheeks and tongue upon the upper surface of the last organ;—the mass being more or less rounded, and hence, usually termed the *alimentary bolus.* Mastication now stops, the tongue is raised and applied against the bony

palate, in succession from the tip to the root, and the alimentary bolus, having no other way of escaping from the force pressing it, is directed towards the pharynx. Previous to this, the pendulous veil of the palate had been applied to the base of the tongue. The bolus now raises it to the horizontal position: the circumflexus palati muscles render the velum tense, so that the food cannot pass into the nasal fossæ; and the muscles that constitute the pillars of the fauces—the palato-pharyngei and the glosso-staphylini—contribute to this effect. By this combination of results, the food is impelled into the pharynx.

The muscles, which, by their action, apply the tongue to the roof of the mouth and to the velum palati, are the proper muscles of the organ, aided by the mylo-hyoidei.

In this first stage of deglutition, the motions are voluntary, except those of the velum palati. The process is not executed with rapidity and is easily intelligible. Such is not the case with the second stage. The actions in it are complicated, and executed with so much celerity, that they have been regarded as a kind of convulsion.

2. The distance, over which the bolus has to travel, in this second stage, is trivial: the rapidity of its course is owing to the larynx or superior aperture of the windpipe, which opens into the pharynx, having to be cleared instantaneously, otherwise respiration would be arrested, and the most serious effects ensue. The mode, in which this second stage is accomplished, is as follows. As soon as the alimentary bolus comes in contact with the pharynx, all is activity; the pharynx contracts, embraces, and presses the bolus; and the velum pendulum, drawn down by the palato-pharyngei and glosso-staphylini muscles, fulfils a similar office. At the same time, the genio-glossus, by applying the tongue to the palate, from the tip to the root, raises the os hyoides, the larynx, and, with it, the anterior paries of the pharynx. The same effect is directly induced by the contraction of the mylo-hyoidei, and genio-hyoidei, muscles; which, instead of acting as depressors of the lower jaw, as they do during mastication, take the jaw as their fixed point, and act as levators of the os hyoides. The larynx is thus elevated, carried forwards, and meets the bolus, to render its passage over the aperture of the larynx shorter, and, therefore, more speedy. To aid this effect, when we make great efforts to swallow, the head is inclined forwards on the thorax.

Whilst the os hyoides and the larynx are raised, they approach each other,—the upper margin of the thyroid cartilage passing behind the body of the hyoid bone: the epiglottic gland is pushed backward, and the epiglottis is depressed, and inclined backwards and downwards, so as to cover the entrance to the larynx. The cricoid cartilage executes a rotatory motion on the inferior cornua of the thyroid cartilage, which occasions the entrance of the larynx to become oblique, from above to below, and, of course, from before to behind. The bolus thus glides over its surface; and, forced on by the veil of the palate, and by the constrictors of the pharynx, reaches the œsophagus.

At one time, it was universally believed, that the epiglottis is the sole agent in preventing substances from passing into the larynx. The experiments of Magendie have, however, demonstrated, that this is the combined effect of the motions of the larynx just described, and of the muscles, whose office it is to close the glottis; so that, if the laryngeal and recurrent nerves be divided in an animal, and the epiglottis be left in a state of integrity, deglutition is rendered extremely difficult;—the principal cause, that prevented the introduction of aliments into the glottis, having been removed by the section. Magendie refers to two cases of individuals, who were totally devoid of epiglottis, and yet, who swallowed without any difficulty; and he remarks, that if, in laryngeal phthisis, with destruction of the epiglottis, deglutition is laboriously and imperfectly accomplished, it is owing to the carious condition of the arytenoid cartilages, and to the lips of the glottis being so much ulcerated as not to be able to close the glottis accurately. Whilst the bolus, then, is passing over the top of the larynx, respiration must be momentarily suspended, owing to the closure of the glottis; and if, owing to distraction of any kind, we attempt to speak, laugh, or breathe, at the moment of deglutition, the glottis opens, the food enters, and the cough is excited, which is not appeased, until the cause is removed. This is what is called, in common language, "the food going the wrong way."

As soon as the bolus has cleared the glottis, the larynx descends, the epiglottis rises, and the glottis opens to give passage to the air. This is owing to the relaxation of the muscles, that had previously raised the larynx and closed the glottis. Chaussier thinks, that the sterno-hyoidei muscles now act, and aid in producing the descent of the parts.

The velum pendulum, then, protects the posterior nares and the orifices of the Eustachian tube from the entrance of the food; and the epiglottis, the elevation of the larynx, with the contraction of the muscles that close the glottis, are the great agents in preventing it from passing into the larynx.

The whole of this second stage consists of rapid movements, of an entirely involuntary character, which, according to Bellingeri, are under the presidency of the palatine filaments of the fifth pair.

3. In the third stage, the pharynx, by its contraction, forces the alimentary bolus into the œsophagus, so as to somewhat dilate the upper part of the organ. The upper circular fibres are thus excited to action, and force the food onward. In this way, by the successive contraction of the circular fibres, it reaches the stomach. In the upper part of the œsophagus, the relaxation of the circular fibres speedily follows their contraction; but this is not the case in the

lowest third, the circular fibres remaining contracted, for some time after the entrance of the bolus into the stomach,—probably to prevent its return into the œsophagus.

The passage of the bolus along the œsophagus is by no means rapid. Magendie affirms, that he was struck, in the prosecution of his experiments, with the slowness of its progression. At times, it was two or three minutes before reaching the stomach; at others, it stopped repeatedly, and for some time. Occasionally, it even ascended, from the inferior extremity of the œsophagus towards the neck, and subsequently descended again. When any obstacle existed to its entrance into the stomach, this movement was repeated a number of times, before the food was rejected. Every one, indeed, must have felt the slowness of the progression of the food through the œsophagus when a rather larger morsel than usual has been swallowed. If it stops, we are in the habit of aiding its progress by drinking some fluid, or by taking a piece of bread to drive it onwards. Occasionally, however, the probang is necessary to move it. The pain, produced in these cases, according to Magendie, is owing to the distention of the nervous filaments, that surround the pectoral portion of the canal.

In the case of a female, labouring under a disease, which permitted the interior of the stomach to be seen, Hallé noticed, that whenever a portion of food passed into the stomach, a sort of ring or *bourrelet* was formed at the cardiac orifice, owing to the mucous membrane of the œsophagus being forced into the stomach, by the contraction of the circular fibres of the canal.

The mucous fluid from the different follicles, pressed out by the passage of the bolus, materially facilitates its progress.

Notwithstanding the facility with which deglutition is accomplished, almost every part of it is uninfluenced by volition, being dependent upon organization, and exerted instinctively. If the alimentary matter, contained in the mouth, be not sufficiently masticated; or if it have not the shape, consistence, and dimensions, that it ought to possess; or if the ordinary movements, that precede mastication, have not been executed, whatever effort we may make, deglutition is impracticable. We constantly meet with persons, who are unable to swallow the smallest pill; yet they can swallow a much larger mass, if certain preliminary motions are permitted, which, in the case of the pill, are inadmissible, in consequence of its being usually of a nauseous character. It appears, that the involuntary parts of the function are excited by the stimulation of the aliment; for, if we attempt to swallow the saliva several times in succession, we find that, after a time, the act is impracticable, owing to the deficiency of saliva. Every one must have experienced the difficulty of deglutition, when the mouth and fauces are not duly moistened by their secretions.

Some individuals are capable of swallowing air; and, according to Magendie, it is an art that can be attained by a little practice.

In the stomach, the air acquires the temperature of the viscus, becomes rarefied, and distends the organ; exciting, in some, a feeling of burning heat; in others, an inclination to vomit or acute pain. Magendie thinks it probable, that its chemical composition undergoes change; but, on this point, nothing certain is known.

The time of its stay in the stomach is variable. Commonly, it ascends into the œsophagus, and makes its exit through the mouth or nostrils. At other times, it passes through the pylorus, and spreads through the whole of the intestinal canal, as far as the anus, distending the abdominal cavity, and simulating tympanites. Magendie refers to the case of a young conscript, who feigned the disease in this manner.

5. *Chymification.* When the food has experienced the changes, impressed upon it by the preceding process, it reaches the cavity of the stomach, where it is retained for several hours, and undergoes the first portion of the true digestive action; being converted into a pultaceous mass, to which the term *chyme* has been applied; and to the process *chymification.*

It does not seem, that all physiologists have employed these terms in this signification; some having confounded the *chyle* with the *chyme;* and *chylification* with *chymification.* The former of these processes is distinctly a duodenal act; whilst the latter is exclusively gastric.

The aliment, as it is sent down by repeated efforts of deglutition, descends into the splenic portion of the stomach; and this without difficulty, as regards the first mouthfuls. The stomach is but little compressed by the surrounding viscera; and its parietes readily separate to receive the alimentary bolus; but when food is taken in considerable quantity, the distention becomes gradually more difficult, owing to the compression of the viscera and the distention of the parietes of the abdomen. The accumulation takes place chiefly in the splenic and middle portions. Dr. Beaumont observed, that when a portion of food was received into the stomach, the rugæ of the latter gently close upon it, and, if it be sufficiently fluid, they gradually diffuse it through the cavity of the organ, entirely excluding more during this action. The contraction ceasing, another quantity of food is received in the same manner. It was found, in the subject of his experiments, that when the valvular portion of the stomach, situated at the fistulous aperture was depressed, and solid food introduced, either in larger pieces or finely divided, the same gentle contraction or grasping motion took place, and continued for fifty or eighty seconds, and would not allow of another quantity, until that period had elapsed, when the valve could be depressed, and more food put in. When he was so placed, that the cardia could be seen, and was then permitted to swallow a mouthful of food, the same contraction of the stomach and grasping of the bolus were invariably observed to commence at the œsophageal ring.

Hence, when food is swallowed too rapidly, irregular contractions of the muscular fibres of the œsophagus and stomach are produced, the vermicular motions of the rugæ are disturbed, and the regular process of digestion is interrupted.

Whilst the stomach is undergoing this distention by the food, it experiences changes in its size, situation, and connexion with the neighbouring organs.

The dilatation does not effect its three coats equally. The two *laminæ* of the peritoneal coat separate, and permit the stomach to pass farther between them. The muscular membrane experiences a true distention; its fibres lengthen, but still so as to preserve the particular shape of the organ; whilst the mucous coat yields, in those parts especially where the *rugæ* are numerous;—that is, along the great curvature and in the splenic portion. In place, too, of being flattened at its anterior and posterior surfaces, and occupying only the epigastrium and a part of the left hypochondrium, it assumes a rounded appearance. Its great *cul-de-sac* descends into that hypochondre and almost entirely fills it, and the greater curvature descends towards the umbilicus, especially on the left side. The pylorus, alone, preserves its position, and its connexion with the surrounding parts;—being fixed down by a fold of the peritoneum. It is chiefly forwards, upwards, and to the left side, that the dilatation occurs. The posterior surface cannot dilate on account of the resistance of the vertebral column, and of a ligamentous formation which prevents the stomach from pressing on the great vessels behind it. Its cardiac and pyloric portions are also fixed; so that when it is undergoing distention, a movement of rotation takes place, by which the great curvature is directed slightly forwards; the posterior surface inclined downwards, and the superior upwards. A wound, consequently, received in the epigastric region, will penetrate the stomach in a very different part, according as it may be, at the time, full or empty.

The dilatation of the stomach produces changes in the condition of the abdomen and its viscera. The total size of the cavity is augmented: the belly becomes prominent; and the abdominal viscera are compressed, sometimes so much so, as to excite a desire to evacuate the contents of the bladder or rectum. The diaphragm, too, is crowded towards the thorax; and is depressed with difficulty; so that, not only is ordinary respiration cramped, but speaking and singing become laborious.

Where the distention of the stomach is pushed to an enormous extent, the parietes of the abdomen may be painfully distended, and the respiration really difficult. It is in these cases of over-distention, that an energetic contraction of the œsophagus is necessary: and hence the advantage of the strong muscular arrangement at its lower portion.

In proportion as the food accumulates in the stomach, the sensation of hunger diminishes; and, if we still go on swallowing additional portions, it entirely disappears, or is succeeded by nausea and loathing. The quantity, necessary to produce this effect, varies according to the individual, as well as to the character of the food; a very luscious article sooner cloying than one that is less so. A due supply of liquid with our solid aliment also enables us to prolong the repast with satisfaction.

As the stomach, when distended, presses upon the different viscera and upon the abdominal parietes, it is obvious, that it must experience a proportionate reaction. An interesting question consequently arises;—to determine the causes, which oppose the passage of the food back along the œsophagus, as well as through the pylorus.

Magendie found, in his vivisections, that the lower portion of the œsophagus experiences, continuously, an alternate motion of contraction and relaxation. This contraction begins at the junction of the two upper thirds with the lowest third; and is propagated, with some rapidity, to the termination of the œsophagus in the stomach. Its duration, when once excited, is variable;—the average being, at least, half a minute. When thus contracted, it is hard and elastic, like a cord strongly stretched. The relaxation, which succeeds the contraction, occurs suddenly and simultaneously in all the contracted fibres; at times, however, it appears to take place from the upper fibres towards the lower. In the state of relaxation, the œsophagus is remarkably flaccid;—forming a singular contrast with that of contraction.

This movement of the œsophagus is, according to Magendie, under the dependence of the eighth pair of nerves. When these nerves were divided in an animal, the œsophagus no longer contracted. Still it was not relaxed. Its fibres, thus deprived of nervous influence, were shortened with a certain degree of force; and the canal remained in a state intermediate between contraction and relaxation.

The lower part of the œsophagus of the horse, for an extent of eight or ten inches, is not contractile in the manner of muscles. Magendie found, that when the eighth pair of nerves was irritated; or when the parts were exposed to the galvanic stimulus, no contraction was produced. The œsophagus of this animal is, however, highly elastic; and its lower extremity is kept so strongly closed, that for a long time after death, it is difficult to introduce the finger into it; and considerable pressure is required to force air into it. This arrangement Magendie considers to be the true reason, why horses vomit with such difficulty as occasionally to rupture the stomach by their efforts.

The alternate motion of the œsophagus, which we have described, opposes the return of the food from the stomach. The more the stomach is distended, the more intense and prolonged is the contraction, and the shorter the relaxation. The contraction, too, commonly coincides with inspiration; the time at which the stomach is, of course, most strongly compressed. The relaxation is synchronous with expiration.

The pylorus prevents the alimentary mass from passing into the duodenum. In living animals, whether the stomach be filled or empty, this aperture is constantly closed by the constriction of its fibrous ring, and the contraction of its circular fibres; and, so accurately is it closed, that, if air be forced into the stomach from the œsophagus, the organ must be distended, and considerable exertion made to overcome the resistance of the pylorus. Yet, if air be forced from the small intestine in the direction of the stomach, the pylorus offers no resistance; suffering it to enter the organ under the slightest pressure;—a circumstance that accounts for the facility with which the bile enters the stomach; especially when there exists any unusual inverted action of the duodenum.

To the pylorus, however, a more active part has been assigned in the passage of the chyme from the stomach into the intestine. "Nothing in the animal economy," say Sir Charles Bell, "is more curious and wonderful than the action of that class of organs of which the pylorus affords a remarkable example. If a portion of undigested food present itself at this door of the stomach, it is not only not permitted to pass, but the door is closed against it with additional firmness: or, in other words, the muscular fibres of the pylorus, instead of relaxing, contract with more than ordinary force. In certain cases, where the digestion is morbidly slow, or where very indigestible food has been taken, the mass is carried to the pylorus before it has been duly acted on by the gastric juice: then, instead of inducing the pylorus to relax, in order to allow of its transmission to the duodenum, it causes it to contract with so much violence as to produce pain, while the food, thus retained in the stomach longer than natural, disorders the organ: and if the digestion cannot ultimately be performed, that disorder goes on increasing until vomiting is excited, by which means the load that oppressed it is expelled. The pylorus is a guardian placed between the first and the second stomach, in order to prevent any substance from passing from the former until it is in a condition to be acted upon by the latter: and so faithfully does this guardian perform its office; that it will often, as we have seen, force the stomach to reject the offending matter by vomiting rather than allow it to pass in an unfit state: whereas, when chyme, duly prepared, presents itself, it readily opens a passage for it into the duodenum."

This view of the functions of the pylorus has antiquity in its favour. It is, indeed, as old as the name, which was given to it, in consequence of its being believed to be a faithful porter or janitor, (πυλωρος, "a porter:") but it is doubtless largely hypothetical. We constantly see substances traverse the whole extent of the intestinal canal, without having experienced the slightest modification in the stomach; yet the pylorus allows them free passage. Buttons, halfpence, &c. have made their way through, without difficulty; as well as the tubes and globes, employed in the experiments of Spallanzani, Stevens and others. There are certain parts of fruits, which are never digested, yet the janitor is always accommodating. Castor oil is capable of being wholly converted into chyle; and would be so, if it could be retained in the stomach; yet there is no agent, which arrests its onward progress. Still, from these, and other circumstances, Broussais has inferred, that there is an internal gastric sense, which exerts an elective agency; detaining as a general rule, substances that are nutritive, but suffering others to pass.

The presence of food in the stomach, after a meal, soon excites the organ to action, although no change in the food is perceptible for some time. The mucous membrane becomes more florid, in consequence of the larger afflux of blood; and the different secretions appear to take place in greater abundance; become mixed with the food, and exert an active and important part in the changes which it experiences in the stomach. Direct experiment has proved, that such augmented secretion actually occurs. If an animal be kept fasting for some time, and then be made to swallow dry food, or even stones, and be deprived of liquid aliment, the substances, swallowed, will be found,—on killing it some time afterwards,—surrounded by a considerable quantity of fluid. Such is not the case with animals, killed after fasting. The stomach then contains no fluid matter. The augmented secretion, in the former case, must therefore, be owing to the presence of the dry food in the stomach. That it is not simply the fluid, passed down by deglutition,—the salivary and mucous secretions, for example,—is proved by the fact, that the same thing occurs when the œsophagus has been tied. Besides, if the stomach of a living animal be opened, and any stimulating substance be applied to its inner surface a secretion is seen to issue, in considerable quantity, at the points of contact; and, again, if an animal be made to swallow small pieces of sponge,—attached to a thread hanging out of the mouth, by means of which they can be withdrawn,—the sponge becomes filled with the fluids secreted by the stomach, and, on withdrawing it, a sufficient quantity can be obtained for analysis. Such experiments have been repeatedly performed by MM. Réaumur, Spallanzani and others. In Dr. Beaumont's case, the collection of gastric secretion was obtained by inserting an elastic gum tube through the opening; in a short time fluid enough was secreted to flow through the tube.

This admixture with the fluids of the mucous membrane of the stomach, and the secretions continually sent down from the mouth, by the efforts of deglutition, is the only apparent change, witnessed for some time after the reception of solid food. Sooner or later, according to circumstances, the pyloric portion of the organ contracts; sending, into the splenic portion, the food it contains: to the contraction dilatation succeeds; and this alternation of movements goes on, during the whole of digestion. After this time, chyme only is found in the pyloric portion, mixed with a very small quantity of unaltered food.

This motion of contraction and relaxation has been called *peristole;* and it appears, at first, to be limited to the pyloric portion of the organ, but it gradually extends to the body and splenic portion, so that, ultimately, the whole stomach participates in it. It consists in an alternate contraction and relaxation of the circular fibres of the stomach; and the gentle oscillation, thus produced, not only facilitates the admixture of the food with the gastric secretions, but exposes fresh portions continually to their action. The experiments of Bichat satisfied him, that the peristole is more marked, the greater the fulness of the stomach. He made dogs swallow forced-meat balls, in the centre of which he placed cartilage, and he found, that when the stomach was greatly charged, the cartilages were pressed out of the balls. This did not happen, when the organ contained a smaller quantity of food.

The ordinary course and direction of the revolutions of the food, according to Dr. Beaumont, are as follows:—The bolus, as it enters the cardia, turns to the left, passes the aperture, descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns in the course of the lesser curvature, and makes its appearance again at the aperture, in its descent into the great curvature to perform similar revolutions. That these are the revolutions of the contents of the stomach, he ascertained by identifying particular portions of food, and by the fact, that the bulb of the thermometer, introduced during chymification, invariably indicated the same movements. Each revolution is completed in from one to three minutes, and the motions are slower at first, than when chymification has made considerable progress.

In addition to these movements, the stomach is subjected to more or less succession from the neighbouring organs. At each inspiration, it is pressed upon by the diaphragm; whilst the large arterial trunks in its vicinity, as well as the arteries distributed over it, subject it to constant agitation.

We have already remarked, that the peristaltic movement of the stomach,—and it extends likewise to the intestines,—is effected by the muscular coat of the organ. It is, however, an involuntary contraction, and appears to be little influenced by the nervous system; continuing, for instance, after the division of the eighth pair of nerves; becoming more active, according to Magendie, as animals are more debilitated, and even at death; and persisting after the alimentary canal has been removed from the body. MM. Tiedemann and Gmelin, however, affirm, that by irritating the plexus of the eighth pair of nerves, which is situated around the œsophagus, with the point of a scalpel, or by touching it with alcohol, the peristaltic action of both stomach and intestines can be constantly excited.

This involuntary function, as well as that exerted by the heart and other involuntary organs, affords us a striking instance of the little nervous influence, that seems to be requisite for carrying on those functions, which have to be executed, independently of volition, through the whole course of existence; and which appear to be produced, chiefly, by the presence of appropriate excitants;—of food, in the case of the peristaltic action of the stomach; of blood, in that of the heart, &c.

The gentle, oscillatory or vermicular motion of the stomach, and the admixture with the fluids, secreted by its internal membrane, as well as by the different follicles, &c. in the supra-diaphragmatic portion of the alimentary canal, are probably the main agents in the digestion operated in the stomach.

Much contrariety of sentiment has existed regarding the precise organs, that secrete the fluid, which oozes out as soon as food is placed in contact with the mucous coat of the stomach. Whilst some believe it to be exhaled from that membrane; others conceive it to be secreted by the numerous follicles, seated in the membrane, as well as in that of the lower portion of the œsophagus; or by what have been termed the *gastric glands.* The analogy of many animals, especially of birds, would render the last opinion the most probable. In them we find, in the second stomach, the cardiac or gastric glands largely developed; and it is probable, that they are the great agents of the secretion of the digestive fluid. (See Fig. 101.) MM. Tiedemann and Gmelin affirm, that the more liquid portion of the gastric fluid is exhaled, and the thicker, more ropy and mucous portion is secreted by the follicles. Rudolphi assigns them a double origin;—from the exhalants, and gastric glands or follicles; whilst Leuret and Lassaigne ascribe their formation exclusively to the villi. Dr. Beaumont, who had an excellent opportunity for experimenting in this matter, remarks, that on applying aliment, or any irritant, to the internal coat of the stomach, and observing the effect through a magnifying glass, innumerable, minute, lucid points, and very fine papillæ, could be seen protruding, from which a pure, limpid, colourless, slightly viscid fluid, distilled, which was invariably distinctly acid. On applying the tongue to the mucous coat in its empty, unirritated state, no acid taste could be perceived. Although no apertures were perceptible in the papillæ, even with the assistance of the best microscope that could be obtained, the points, whence the fluid issued, were clearly indicated by the gradual appearance of innumerable, very fine, lucid specks, rising through the transparent mucous coat, and seeming to burst, and discharge themselves upon the very points of the papillæ, diffusing a limpid, thin fluid over the whole interior gastric surface.

A like difference of opinion has prevailed regarding the chymical character of the fluids; and this has partly arisen from the difficulty of obtaining them identical. The true fluid, secreted by the gastric follicles or mucous membrane, can never, of course, be obtained for examination in a state of purity. It must always be mixed, not only with the other secretions of the stomach, but with all those sent down into the organ, by the constant efforts of deglutition. It is, consequently, to this mixed fluid, that the term *gastric juice* has really been applied; although it is more especially appropriated to the particular fluid, presumed to be secreted by the stomach, and to be the great agent in digestion. To the nature of the gastric juice and its effect in the process of digestion, we shall have occasion to recur presently.

It is probably owing to the quantity of fluid, secreted by the stomach, that it is so largely supplied with blood-vessels; and that the mucous membrane is more injected, during the presence of food in the stomach. Experiments, by Sir Benjamin Brodie and others, would seem to show, that this secretion is under the influence of the eighth pair of nerves. Having administered arsenic to different animals,—in some of which he had divided the eighth pair of nerves,—he found, that, whilst the stomach of those, in which the nerves were unaffected, contained a large quantity of a thin, mucous fluid; in those, whose nerves were divided, the organ was inflamed and entirely dry. Leuret and Lassaigne, however, affirm, that the division of these nerves had no influence on the gastric secretion. But more of this presently.

Before entering into the views of different physiologists on chymification; or, in other words, on the theories of digestion; it will be well to refer to the physical and chymical properties of the chyme. Whether the changes, induced upon the food, are simply physical or chymical, or whether the first stage of animalization is effected within the stomach, will be a topic for future inquiry.

Chyme is a soft, homogeneous substance, of a grayish colour and acid taste. Such, are its most common characters; it varies, however, according to the food that has been taken, as may be easily observed, by feeding animals on different simple alimentary substances, and killing them during the process of digestion. This difference, in its properties, accounts for the discrepancy, observable in the accounts of writers on the subject.

The change, wrought on the aliments, is, doubtless, of a chymical nature; but the new play of affinities is controlled by circumstances inappreciable to us. In the case of a female patient, at the hospital *La Charité*, of Paris, who had been gored by a bull, and had a fistulous opening in the stomach, the food, during its conversion into chyme, appeared to have acquired an increase of its gelatine; a greater proportion of the muriate and phosphate of soda and phosphate of lime, and a substance, in appearance, fibrinous. Marcet however affirms, that he could never discover gelatine in it.

It has been said, again, that the food becomes decarbonized and more azoted; that the carbon, which disappears, is removed by the oxygen of the air swallowed with the food, or by that contained in the food itself; and that the azote proceeds, in greater quantity, from the secretions of the stomach, or predominates simply because the food is decarbonized. Adelon has properly remarked, that the fact and the explanation are here equally hypothetical. Generally, the chyme possesses acid properties. MM. de Montègre and Magendie, and Tiedemann and Gmelin always found it so. Haller and Marcet found it to be neither acid nor alkaline. In the chyme, examined by the latter gentleman, he detected albumen, an animal matter, and some salts, differing, however, slightly, according as it proceeded from animal or from vegetable food. In the latter case, for example, it afforded four times as much carbon as in the former, but less saline matter; and this consisted of lime and an alkaline chloruret. MM. Leuret and Lassaigne analyzed the chyme from the stomach of an epileptic, who died suddenly in a fit five or six hours after having eaten. The chyme was of a white, slightly yellowish colour, and of a strong, disagreeable taste. On analysis, it afforded a free acid,—the lactic; a white, crystalline, slightly saccharine matter, analogous to the sugar of milk; albumen, soluble in water; a yellowish, fatty, acid matter, analogous to rancid butter; an animal matter, soluble in water, having all the properties of caseum; and a little muriate of soda, phosphate of soda, and much phosphate of lime. Lastly, Prout affirms, that a quantity of muriatic acid is present in the stomach, during the process of digestion. He detected it in the stomachs of the rabbit, hare, horse, calf, and dog, and in the sour matter, ejected from the stomachs of persons, labouring under indigestion:—a fact which has since been confirmed by Mr. Children.

MM. Tiedemann and Gmelin, and Dr. Beaumont, affirm, that the secretion of acid commences, as soon as the stomach receives the stimulus of a foreign body, and that it consists of the muriatic and acetic acids. The experiments of these gentlemen were not confined to the chymous mass, obtained from digestible food. They examined the fluids, secreted by the mucous membrane, when indigestible substances were sent into the stomach, and the acid character was equally manifested. These experiments, consequently, remove an objection, made by Bostock, regarding the detection of the muriatic acid by Prout;—that, as there did not appear to be any evidence of the existence of this acid, before the introduction of food into the stomach, it might rather be inferred, that it is, in some way or other, developed during the process of digestion. In all Dr. Beaumont's experiments, the chyme, as before observed, was invariably distinctly acid.

The principal theories on chymification have been the following:—

1. *Coction*, or *elixation*.—This originated with Hippocrates, and was vaguely used by him to signify the maceration and maturation from the raw state, experienced by the food in the stomach. The doctrine was embraced by Galen, and others, who ascribed to the

organ, an *attracting*, *retaining*, *concocting*, and *expelling* quality effected by heat.

In proof of this, they affirmed, that the heat of the stomach is increased during chymification; that the process is more rapid in the warm, than in the cold-blooded animal; that it is aided by artificial heat, and continues even after death, if care be taken to keep up the heat of the body; that in the experiments on artificial digestion, made by Spallanzani, heat was always necessary, and the greater the degree of heat the more easy and complete the digestion. It is hardly necessary, however, to say, that the heat of the stomach is totally insufficient to excite any coction or ebullition, in the physical sense of the term, and this applies, particularly, to the cold-blooded animal, which must digest, if not with the same, with due, rapidity.

2. *Putrefaction.*—The next great hypothesis was that of *putrefaction*, which, we are informed by Celsus, was embraced by Plistonicus, a disciple of Praxagoras of Cos, who flourished upwards of three hundred years before the birth of Christ. Of late, it has had no advocates, but it appears to have been the view embraced by Cheselden. The reasons, urged in favour of it, have been;—the putrescible character of the materials employed as food; the favourable circumstances of a heat of 98° or 100°, and of moisture; and, by some, the fœtor of the excrements. The objections are, 1. That when the contents of the stomach are rejected, during chymification, they exhibit no evidence of putridity. 2. That in all the experiments, which have been made on the comparative digestibility of different substances, where it has been necessary to kill the animals, at different stages of the digestive process, there has not been the slightest sign of putrefaction. 3. That opportunities frequently occur, for witnessing ravenous fishes and reptiles with an animal or part of an animal,—which has been too large to be entirely swallowed,—partly in the stomach and the remainder in the gullet and mouth. This we have seen, more than once, in the case of the pike, which has been choked by attempting to swallow a trout larger than itself. In all these cases, where the food has remained in this situation for some days, the part of it, contained in the throat, has been found putrid, whilst that in the stomach has been entirely sweet; and, lastly, in Spallanzani's and other experiments, to be detailed presently, it was found, that, when food, in a state of putridity, was taken into the stomach, or mixed with the gastric juice out of the stomach, it recovered its sweetness. It has been already observed, that it is the custom, in some countries, to eat the *gibier* or *game* in a state of incipient putrefaction; yet the breath is not in any way tainted by it.

Trituration.—The mathematical physiologists,—Borelli, Hecquet, Megallotti, Pitcairne, Redi, and others—after the example of Erisistratus, attempted to refer the whole process of digestion to *trituration*, imagining, that the food is subjected, in the stomach, to an action, similar to that of the pestle and mortar of the apothecary, or of the millstone, and that the chyle is formed like an emulsion.

The most plausible arguments, in favour of this view of the subject, are drawn from the presumed analogy of the granivorous bird, whose stomach is capable of exerting an astonishing degree of pressure on substances submitted to its power. There is no analogy, however, between the human stomach, and the gizzard of birds. The latter is a masticatory organ, and therefore possessed of the surprising powers which we have elsewhere described; whilst mastication, in man, is accomplished by distinct organs. No comparison can, indeed, be instituted between the gentle oscillatory motion of the stomach, and the forcible compression, exerted by the digastric muscle of the gizzard. The simple introduction of the finger, through a wound of the abdomen, has shown, that the compression, exerted by it on its contents, is totally insufficient to bruise any resisting substance. Moreover, we constantly see fruits,—as raisins and currants,—passing through the whole intestinal canal unchanged; whilst worms remain in the stomach,—reside there,—unhurt; and, we shall see presently, that the experiments of Réaumur and Spallanzani, proved most convincingly, that digestion is effected independently of all pressure. The futility, indeed, of this mode of viewing the subject, is signally illustrated by the fact, that, whilst Pitcairne estimated the power of the muscular fibres of the stomach at 12,951 pounds, Hales thought that twenty pounds would come nearer to the truth; and Astruc valued its compressive force at five ounces.

4. *Fermentation.*—The system of *fermentation* had many partisans; amongst whom may be mentioned Van Helmont, Sylvius, Willis, Boyle, Grew, Charleton, Lower, Raspail, &c. Digestion, in this view, was ascribed to the chymical reaction of the elements of the food upon each other, during their stay in the stomach;—the action being excited by some of the food, which had already undergone digestion, or by a leaven, secreted, for the purpose, by the stomach itself.

In favour of this view, it was attempted to show, that air is constantly generated in the stomach, and that an acid is always produced as the result of fermentation; the formation of chyme being assigned, by the greater number of physiologists, to the vinous and acetous fermentations.

The objections to the doctrine of fermentation are;—that digestion ought to be totally independent of the stomach, except as regards temperature; and that the food ought to be converted into chyme, exactly in the same manner,—if it were reduced to the same consistence, and placed in the same temperature,—out of the body; which is found not to be the case. Bones are speedily reduced to chyme in the stomach of the dog, although they would remain unchanged for weeks, in the same temperature, out of the body. The facts of the voracious fishes likewise prove the insufficiency of this hypothesis; according to which, digestion ought to be accomplished as effectually in the œsophagus as in the stomach. Yet it is found, in these cases, that, whilst the portion in the stomach is digested, the other may be unaltered, or it may be putrid.

The truth is; in healthy digestion, fermentation does not occur; and, whenever the aliments of the food react upon each other, it is an evidence of imperfect digestion; and, hence, is one of the most common signs of dyspepsia.

5. *Maceration.*—Haller supposed, that the food is merely diluted and softened by the fluids in the stomach; and that this maceration is favoured and accelerated by the warmth of the part, by incipient putrefaction, and by the gentle and constant motion, by which the food is agitated. Maceration, however, requires a much longer time to destroy the cohesive force of resisting substances than digestion; and, moreover, the product is not chyme. It is, consequently, insufficient for the explanation of the process. Haller's opinion was chiefly formed from the forced analogy of ruminant animals, in which the food is subjected to fresh mastication and comminution, before it descends into the third and fourth stomachs. Independently, however, of the fact, that no parallel can be drawn between the stomach of the herbivorous animal, and that of man, it must be borne in mind, that the important, and truly digestive changes, effected upon the food, take place in the fourth stomach, and not in those concerned in rumination.

6. *Chymical solution.*—The theory of chymical solution, as proposed by Spallanzani, has met with more favour from physiologists than any of the others that have been mentioned. It may now, we think, be regarded as completely established. According to him, chymification is owing to the solvent action of a fluid, secreted by the stomach, accumulating in that viscus between meals and during hunger,* and acting as a true menstruum on the substances exposed to its action. This fluid,—to which he gave the name *gastric juice*,—he affirmed to be peculiar in each animal, according to its kind of alimentation,—a fact confirmed by the experiments of Voisin—corresponding, as regards its energy, with the rest of the digestive apparatus, and differing in its source in the series of animals; proceeding, in some, from the follicles of the œsophagus; in others from those of the stomach itself; but always identical in the same animal; generally transparent, slightly yellow, of a saline taste, bitter, slightly volatile, and stronger in animals with a membranous than in those with a muscular stomach, and than in ruminant animals.

To obtain this juice, Spallanzani opened animals, after they had been made to fast for some time; and collected the juice, accumulated in their stomachs; or he made them swallow tubes,

* It has been already shown, that the experiments of Dr. Beaumont have satisfactorily proved that no such accumulation takes place during hunger

pierced with holes, and filled with small sponges. By withdrawing these tubes, by means of a thread attached to them, and suffered to hang out of the mouth, and expressing the sponges, he obtained the fluid, in quantity sufficient for examination.

To determine whether this fluid, obtained from the stomach of fasting animals, was destined to chymify the food, Spallanzani tried the following experiments. He caused numerous animals to swallow tubes filled with food, but pierced with holes, so that the juices of the stomach might be able to get into their interior; and he found that chymification was effected, when he had taken the precaution to chew the substances before they were put into the tubes, or to triturate them; and the process was always more readily accomplished, the more easy the access of the fluids. On repeating these experiments on animals of all kinds, with a muscular or membranous, or musculo-membranous stomach; on pullets, turkeys, ducks, pigeons, rooks, frogs, salamanders, eels, serpents, sheep, cats, &c., he always obtained the same results; and hence he affirmed, that trituration cannot be the essence of chymification; and that it does not exist in animals with a membranous stomach. Réaumur,—originally a believer in the doctrine of trituration,—had previously proved this fact by experiments of a similar kind.

Spallanzani next repeated those experiments upon himself. Having well chewed different articles of food, he inclosed them in wooden tubes pierced with holes, and swallowed them; but, as these tubes excited pain in the bowels, he substituted small bags of solid linen. The substances contained in the interior of the bags were digested, without the bags being torn: a fact, which proved that digestion must have been accomplished by means of a fluid, which penetrated them. In 1777, Stevens repeated these experiments. He made an individual swallow balls of metal, filled with masticated food, and pierced with holes: when these balls were voided,—thirty-six or forty-eight hours afterwards, they were entirely empty.

Lastly.—Spallanzani was desirous of seeing whether this solvent juice could effect digestion out of the body. He put some well masticated food in small glass tubes, and mixed gastric juice with it. These tubes he placed in his axilla, in order that they might be exposed to the same degree of heat as in the stomach; and he affirms, that in the space of fifteen hours, or of two days,—more or less,—the substances appeared to be converted into chyme. In these experiments he found it important to employ gastric juice, which had not previously been used, and to have a sufficient quantity of it.

From all these experiments, Spallanzani conceived it to be demonstrated, that chymification is a true chymical solution; and he endeavoured to deduce from them the degree of digestibility of different substances.

Similar experiments were instituted by Dr. Beaumont. In all cases, solution occurred as perfectly in the *artificial* as in the *real* digestions, but they were longer in being accomplished, for reasons, which appear sufficient to explain the difference. In the former, the gastric secretion is not continuous; the temperature cannot be as accurately maintained, and there is an absence of those gentle motions of the stomach, which are manifestly so useful in accomplishing the real digestion.

With regard to the precise nature of this gastric juice of Spallanzani, we have already observed that great contrariety of sentiment has prevailed; and that in ordinary cases, it is impracticable to procure it unmixed with the other fluids of the digestive mucous membrane. Spallanzani affirmed, that the only properties he detected in it, were,—a slightly salt, bitterish taste; but that it was neither acid nor alkaline. Gosse found it to vary according to the nature of the animal,—whether herbivorous or carnivorous;—and to be always acid in the former. Dumas held the same sentiments, and proved, by experiments on dogs, that it was acid or alkaline, according as the animal had fed on vegetable or on animal diet. He declared it, moreover, to be mawkish, thick, and viscid. Viridet, Werner, Hunter, and others, affirm, that it is always acid. Scopoli analyzed the gastric juice of the rook, and found it to consist of water, gelatine, a saponaceous matter, muriate of ammonia, and phosphate of lime. Carminati describes it as salt, and bitter, and frequently acid; and MM. Macquart and Vauquelin, in the gastric juice of the ruminant animal, found albumen and free phosphoric acid.

All these analyses were made on the mixed fluid, to which the term *gastric juice* has been applied.

That such a mixed fluid does exist in the stomach, at the time of chymification, and is largely concerned in the process, is proved by the facts already mentioned, as well as by the following.

Magendie asserts, that one of his pupils—M. Pinel—could procure, in a short time after swallowing a little water or solid food, as much as half a pint of it. M. Pinel "possessed the faculty of vomiting at pleasure." In this way, he obtained from his stomach, in the morning, about three ounces of the fluid, which was analyzed by Thénard, who found it composed of a considerable quantity of water, a little mucus, some salts with a base of soda and lime but it was not sensibly acid, either to the tongue or to reagents. On another occasion, Pinel obtained two ounces of fluid, in the same manner. This was analyzed by Chevreul, and found to contain much water, a considerable quantity of mucus, lactic acid,—united to an animal matter, soluble in water, and insoluble in alcohol;—a little muriate of ammonia, muriate of potassa, and some muriate of soda.

Tiedemann and Gmelin procured the gastric fluid by making animals, that had fasted, swallow indigestible substances, such as flints. It always appeared to them to be produced in greater quantity, and to have a more acid character, in proportion as the alimentary matter was less digestible and less soluble; and they assign it, as constituent elements,—muriatic acid; acetic acid; mucus; no, or very little, albumen; salivary matter; osmazome; muriate, and sulphate of soda. In the ashes, remaining after incineration, were,—carbonate, phosphate and sulphate of lime, and chloride of calcium. Leuret and Lassaigne assign its composition, in one hundred parts, to be,—water, ninety-eight; lactic acid, muriate of ammonia, muriate of soda, animal matter soluble in water, mucus and phosphate of lime, two parts. In the winter of 1832-3, the author was favoured, by Dr. Beaumont, with a quantity of the gastric secretion, obtained from the individual with the fistulous opening into the stomach, which was examined by Professor Emmett, of the University of Virginia, and himself, and found to contain free muriatic and acetic acids, phosphates, and muriates, with bases of potassa, soda, magnesia and lime, with an animal matter soluble in cold water, but insoluble in hot. The quantity of free muriatic acid was surprising: on distilling the gastric fluid, the acids passed over, the salts and animal matter remaining in the retort. The quantity of chloride of silver, thrown down on the addition of the nitrate of silver to the distilled fluid was astonishing.

The author had many opportunities of examining the gastric secretion obtained from the case in question. At all times, when pure or unmixed, except with a portion of the mucus of the lining membrane of the digestive tube, it was a transparent fluid, having a marked smell of muriatic acid; of a slightly salt, and very perceptibly acid, taste. The source of the chlorine or muriatic acid, as Dr. Prout suggests, must be the common salt, existing in the blood, which he conceives to be decomposed by galvanic action. The soda, which is set free, remains, he thinks, in the blood, a portion of it being "requisite to preserve the weak alkaline condition essential to the fluidity of the blood;" but the larger part being directed to the liver to unite with the bile. This is plausible, but it need scarcely be added, not the less hypothetical.

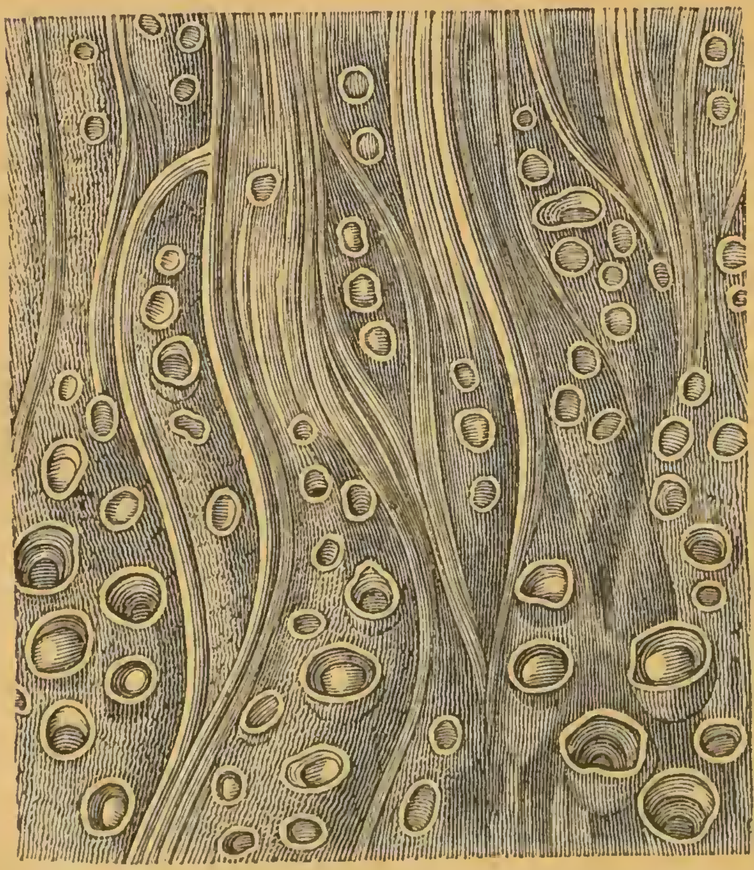
Still, the diversity of the results obtained by chymical analysts; the difficulty of comprehending how the same fluid can digest substances of such opposite character; and the uncertainty we are in, regarding the organs concerned in its production, have led some physiologists to doubt the existence of any such *gastric juice* or solvent, as that described by Spallanzani. Montègre, for example, in the year 1812, presented to the French Institute a series of experiments, from which he concluded, that the gastric juice of Spallanzani was nothing more than saliva, either in a pure state or changed by the chymifying action of the stomach and become acid. As Montègre was able to vomit at pleasure, he obtained the gastric juice, as it had been done by previous experimenters, in this manner, whilst fasting. He found it frothy, slightly viscid, and turbid; depositing, when at rest, some mucous flakes, and commonly acid; so much so, indeed, as to irritate the throat, and to render the teeth rough. He was desirous of proving, whether this fluid was in any manner inservient to chymification. For this purpose, he began by rejecting as much as possible by vomiting; and, afterwards, swallowed magnesia to neutralize what remained of it. On eating after this, the food did not appear less chymified; nor was it less acid; whence he concluded, that, instead of this fluid being the agent of chymification, it was, itself, nothing more than the saliva and the mucous secretions of the stomach, changed by the chymifying action of that viscus. To confirm himself in this view, he repeated, with this juice, Spallanzani's experiments on artificial digestion; making, at the same time, similar experiments with saliva, and the results were the same in the two cases. When gastric juice, not acid, was put into a tube, and placed in the axilla,—as in Spallanzani's experiments,—in twelve hours it was in a complete state of putrefaction. The same occurred to saliva, placed in the axilla. Gastric juice, in an acid state, placed in the axilla, did not become putrid, but this seemed to be owing to its state of acidity; for the same thing happened to the saliva, when rendered acid by the addition of a little vinegar, and even to the gastric juice,—used in the experiment just referred to,—when mixed with a little vinegar. Again, he attempted artificial digestions with the gastric juice, acid and not acid, fresh and old; but they were unsuccessful. The food always became putrid, but sooner, when the juice employed was not acid; and, if it sometimes liquefied, before becoming putrid, this was attributed to the acidity of the juice, as the same effect took place, when saliva, mixed with a little vinegar, was employed. Montègre, moreover, observed, that the food, rejected from the stomach, was longer in becoming putrid, in proportion to the time it had been subjected to the chymifying action of the stomach; and he concluded, that the fluid, which is sometimes contained in the stomach when empty, instead of being a menstruum kept in reserve for chymification, is nothing more than the saliva, continually sent down into that viscus, and that its purity or acidity depends upon the chymifying action of the stomach.

As regards the fluid, met with in the stomach of fasting animals, Montègre's remarks may be true in the main; but we have too many evidences in favour of the chymical action of some secretion from the stomach during digestion to permit us to doubt for a moment of the fact. Besides, some of the experiments of Montègre have been repeated and with opposite results. MM. Leuret and Lassaigne, and Dr. Beaumont, for example, performed those relating to artificial digestion after the manner of Spallanzani, and succeeded perfectly; whilst they failed altogether in producing chymification with the saliva, either in its pure state, or acidulated with vinegar.

But even were the evidence adduced less positive, the following would be overwhelming, in favour of the existence of some secretion from the stomach, concerned in the digestive changes in that organ.—Besides the fact of the most various and firm substances being reduced into chyme in the stomach, we find the secretions from its lining membrane possessing the power of coagulating albuminous fluids. It is upon the coagulating property of these secretions, that the method of making cheese is dependent. Rennet, employed for this purpose, is an infusion of the digestive stomach of the calf, which, on being added to milk, converts the albuminous portion of it into the state of curd; and it is surprising how small a quantity of the rennet is necessary to produce this striking effect. Fordyce and Young found, that six or seven grains of the inner coat of a calf's stomach, infused in water, afforded a liquid, which coagulated more than one hundred ounces of milk,—that is, more than six thousand eight hundred and fifty-seven times its own weight; and yet its weight was probably but little diminished. What the substance is, that possesses this property, is not known to the chymist. It appears not to be very soluble in water; for the inside of a calf's stomach, after having been steeped in water for six hours, and then well washed, still furnishes a liquor on infusion, which coagulates milk.

Mr. Hunter made numerous experiments upon the coagulating power of the secretions of the stomach, which show, that it exists in the stomachs of animals of very different classes. The lining of the fourth stomach of the calf is in common use, in a dried state, for the purpose mentioned above; and it has been proved, that every part of the membrane possesses the same property. Hunter found, by experiment, that the mucus of the fourth cavity of a slink calf, made into a solution with a small quantity of water, had the power of coagulating milk; but that found in the three first cavities, possessed no such power. This mucus, even after it had been kept several days, and was beginning to be putrid, retained the property. The duodenum and jejunum, with their contents, likewise coagulated milk; but the process was so slow, as to give rise to the suggestion, that it might have occurred independently of the intestines employed for the purpose. He found, that the inner membrane of the fourth cavity in the calf, when old enough to be killed for veal, had the same property. Portions of the cuticular part, of the massy glandular part, and of the portion near the pylorus of the boar's stomach, being prepared as rennet, it was found, that no part had the effect of producing coagulation but that near the pylorus, in which part the gastric glands of the animal are especially conspicuous. The crop and gizzard of a cock were salted, dried, and afterwards steeped in water. The solution, thus obtained, was added to milk. The portion of the crop coagulated it in two hours, that of the gizzard in half an hour. The contents of a shark's stomach and duodenum coagulated milk immediately. Pieces of the stomach were washed clean, and steeped for sixteen hours in water. The solution coagulated milk immediately. Pieces of the duodenum produced the same effect. When the milk was heated to 96°, the coagulation took place in half an hour; when it was cold, in an hour and a quarter. The stomachs of the salmon and thornback, made into rennet, coagulated milk in four or five hours. But these experiments of Mr. Hunter do not inform us of the particular secretions, that are productive of the effect. They would, indeed, rather seem to show, that it is a general property of the whole internal membrane. To discover the exact seat of the secretion, and especially whether it be not in the gastric glands, Sir Everard Home selected those of the turkey; which, from their size, are better adapted for such an experiment than those of any other bird, except the ostrich. A young turkey was kept a day without food, and was then killed. The gastric glands were carefully dissected separately from the lining of the cardiac cavity; cutting off the duct of each before it pierced the membrane, so that no part but the glands themselves were removed. Forty grains, by weight, of these glands were added to two ounces of new milk; and similar experiments were made with rennet; with the lining of the cardiac cavity of the turkey; and with the inner membrane of the fourth cavity of the calf's stomach. Coagulation, and the separation into curds and whey, were first effected by the rennet. Next to this, and simultaneously, came the gastric glands, and the fresh stomach of the calf; and lastly the cardiac membrane of the turkey.

Fig. 108.



Gastric glands of the œsophagus magnified fifteen times.

From these experiments, Sir Everard concluded, that the power of coagulation is in the secretion of the gastric glands; and that this power is communicated to other parts, by their becoming more or less impregnated with it.

The marginal figure, copied from an engraving by Sir Everard Home, of the microscopic observations of Mr. Bauer, exhibits the gastric glands, situated in the human œsophagus, magnified fifteen times. These glands are in the lining of the lower part of the œsophagus; and have the appearance of infundibular cells, whose depth does not exceed the thickness of the membrane. This structure, although different from that of the gastric glands of birds, is a nearer approach to it, than is to be met with in any part of the inner surface of the stomach or duodenum. It also resembles them, in the secretion it produces coagulating milk, whilst none of the inspissated juices, met with in these cavities, according to Sir Everard, affect milk in the same way. From these facts, he thinks, there can be no longer any doubt entertained, that the gastric glands have the same situation respecting the cavity of the stomach as in birds. Yet M. Montègre denies that the gastric juice has any coagulating power!

Another property, manifestly possessed by the secretion in question, is that of preventing putrefaction, or of obviating it, in substances, exposed to its action. Montègre and Thackrah deny it this property also, but there can be no doubt of its existence. Spallanzani, Fordyce, and others, have ascertained, that, in those animals, that frequently take their food in a half putrid state, the first operation of the stomach is to disinfect, or remove the fœtor from, the aliment received into it. We have already alluded to many facts, elucidative of this power. Helm, of Vienna, in the case of a female, who had a fistulous opening in her stomach, observed, that substances, which were swallowed in a state of acidity, or putridity, soon lost those qualities in the stomach; and the same power of resisting and obviating putrefaction has been exhibited in experiments, made out of the body. Nothing could be more unequivocal as regards the possession of this property by the gastric fluid, than the experiments of Dr. Beaumont and the author, with the secretion obtained from the subject of his varied investigations. In the presence of the author's friend, N. P. Trist, Esq.,—the consul of the United States at the Havanna,—the odour of putrid food was as speedily removed by it, as by the chloride of soda, employed at the same time on other portions.

The explanation of this property, as well as that of coagulation, has been a stumbling-block to the chymical physiologist. "We can only say concerning it," says Dr. Bostock, "that it is a chymical operation, the nature of which, and the successive steps by which it is produced, we find it difficult to explain; at the same time, that we have very little, in the way of analogy, which can assist us in referring it to any more general principle, or to any of the established laws of chymical affinity."

The cases of what are termed *digestion of the stomach after death* afford us, likewise, remarkable examples of the presence of some powerful agent in the stomach; as well as of the resistance to chymical action, offered by living organs. Powerful as the action of the gastric juice may be in dissolving alimentary substances, it does not exert it upon the coats of the stomach during life. Being endowed with vitality, they effectually resist it. But when that viscus has lost its vitality; its parietes yield to the chymical power of the contained juices; and become softened, and, in part, destroyed. Hunter found the lining membrane of the stomach destroyed, in several parts, in the body of a criminal, who, for some time before his execution, had been prevailed upon, in consideration of a sum of money, to abstain from food. Since Hunter's time, numerous examples have occurred, and have been recorded by Baillie, Allan Burns, Haviland, Grimaud, Pascalis, Cheeseman, J. B. Beck, Chaussier, Yelloly, Gardner, Treviranus, Gödecke, Jäger and others.

The fact is of importance in medical jurisprudence; and, until a better acquaintance with the subject would, doubtless, have been set down as strong corroborative evidence in cases of suspected poisoning. It is now established, that solution of the stomach may take place after death, without there being the slightest reason for supposing, that anything noxious has been swallowed.

The experiments of Drs. Wilson Philip and Carswell, are signally corroborative of this physiological action of the gastric juice. On opening the abdomen of rabbits, which had been killed immediately after having eaten, and were allowed to lie undisturbed for some time before examination, the former found the great end of the stomach soft, eaten through, and sometimes altogether consumed; the chyme being covered only by the peritoneal coat, or lying quite bare for the space of an inch and a half in diameter; and, in this last case, a part of the contiguous intestines was also destroyed; whilst the cabbage, which the animal had just taken, lay, in the centre of the stomach, unchanged, if we except the alteration that had taken place, in the external parts of the mass it had formed, in consequence of imbibing gastric fluid from the half-digested food in contact with it. Why the perforation takes place, without the food being digested, is thus explained by Dr. Philip.

Soon after death, the motions of the stomach, which are constantly carrying on towards the pylorus the most digested food, cease. The food, which lies next to the surface of the stomach, becomes, thus, fully saturated with gastric fluid, neutralizes no more, and no new food being presented to it, it necessarily acts on the stomach itself, now deprived of life, and equally subject to its action with other dead animal matter. It is extremely remarkable, however, that the gastric fluid of the rabbit, which, in its natural state, refuses animal food, should so completely digest its own stomach, as not to leave a trace of the parts acted upon.

Dr. Philip remarks, that he has never seen the stomach eaten through except in the large end; but, in other parts, the external membrane has been injured. Mr. A. Burns, however, affirms, that, in several instances, he found the forepart of the stomach perforated, about an inch from the pylorus, and midway between the smaller and larger curvatures.

From all these facts, then, we are justified in concluding, that the food in the stomach is subjected to the action of a secretion, which alters its properties, and is the principal agent in converting it into chyme.

But many physiologists, whilst they admit, that the change effected in the stomach is of a chymical character, contend, that the nature of the action is unlike what takes place in any other chymical process, and that it is, therefore, necessarily *organic* and *vital*, and appertaining to *vital chymistry*. Such are the sentiments of Fordyce, of Broussais, of Chaussier and Adelon, and others. Prout suggests, that the stomach must have within certain limits, the power of *organizing* and *vitalizing* the different alimentary substances; so as to render them fit for being brought into more intimate union with a living body, than the crude aliments can be supposed to be. It is impossible, he conceives, to imagine, that this organizing agency of the stomach can be chymical. It is vital, and its nature completely unknown. The physiologist should not, however, have recourse to this explanation, until every other has failed him. It is, in truth, another method of expressing our ignorance, when we affirm that any function is executed in an *organic* or *vital* manner; nor is this mode of explaining the conversion of the aliment into chyme necessary. The secretion of the fluid, which is the great agent of chymication, is doubtless vital; but when once secreted, the changes, effected upon the food, are probably unmodified by any vital interference, except what occurs from temperature, agitation, &c., which can only be regarded as auxiliaries in the function.

It is, in this way, that digestion is influenced by the nervous system. The effect of the different emotions upon the digestive function is often evinced, and has already been alluded to; but the importance of the nervous influence to this function has been elucidated, in an interesting manner to the physiologist, of late years chiefly. Baglivi, having tied the two nerves of the eighth pair in dogs, found that they were affected with nausea and vomiting, and that they obstinately refused food. Since Baglivi's time, the same results have been obtained by many physiologists. De Blainville, having repeated the operation on pigeons, found the vetch, in their crops, entirely unchanged, and chymification totally prevented. Legallois, Brodie, Philip, Dupuy, Clarke Abel, Hastings, and others, on carefully repeating the experiments, also announced, that, after this operation, the digestive process was entirely suspended.

The result of these experiments was, however, contested by several physiologists of eminence, who affirmed, that, after the division of the eighth pair of nerves, digestion continued nearly in the natural state, or, at most, was only slightly impeded. Mr. Broughton asserted, that he had made the section on eleven rabbits, one dog, and two horses; and that digestion was not destroyed. Magendie expressed his belief, that the annihilation of chymification was owing to the disturbance of respiration, caused by the division of the nerves; and he affirmed that digestion continued, when care was taken to cut the nerve within the thorax, lower down than the part, which furnishes the pulmonary branches. MM. Leuret and Lassaigne assert, that they found chymification continue, notwithstanding the division of these nerves; and Dr. Holland thinks he has proved, that the suspension of the digestive function is not produced by the influence of these nerves being withdrawn from the stomach, but by the disturbance of the circulating system; for when the natural conditions of this system were maintained, after the division of the nerves in question, the function of digestion still continued to be properly performed; showing that the nervous connexion between the brain and stomach is not essential to the process of digestion, to the secretion of the gastric solvent, or to the possession of contractility by the muscular fibres of the stomach.

In opposition to these experiments, those of Dupuytren may be adduced. He divided, separately, the portions of the eighth pair of nerves, distributed to the pulmonary, circulatory, and digestive apparatuses, and always found, that, when the section was made below the pulmonary plexus, chymification was suspended. But how are we to explain the discrepancy between these results, and those of MM. Broughton and Magendie? Adelon has supposed, that as the eighth pair is not the only nerve distributed to the stomach,—the great sympathetic sending numerous filaments to it,—these filaments, in the experiments of MM. Broughton and Magendie, may have been sufficient to keep up for some time the chymifying action of the stomach; and, again, he suggests, whether the nervous influence of the stomach may not have still persisted for a time after the section of the nerve, like other nervous influences, which, he conceives, continue for some time, even after death; and, lastly, he thinks it probable, that, in the cases, in which chymification continued, the experiment was badly performed. Most of these reasons, however, would apply with as much force to the experiments on the other side of the question. Why were not the agency of the great sympathetic, and the continuance of the nervous influence for some time after the section of the nerve, evidenced in the experiments of Dupuytren, and of Wilson Philip, Hastings, and others?

More recent experiments by Wilson Philip, Breschet, Milne Edwards, and Vavasseur, have shown, that the mere division of the nerves, and even the retraction of the divided extremities for the space of one-fourth of an inch, does not prevent the influence from being transmitted along them to the stomach; but that, if a portion of the nerve be actually removed, or the ends folded back, chymification is wholly, or in part, suspended.

Most of the experimenters agree with Sir Benjamin Brodie in the opinion, that chymification is suspended, owing to the secretion of the gastric juice having been arrested, by the division of the nerves under whose presidency it is accomplished. MM. Breschet and Milne Edwards, however, conceive, that the effect is owing to paralysis of the muscular fibres of the stomach produced by the section of the nerves; in consequence of which the different portions of the alimentary mass are not brought properly into contact with the coats of the stomach, so as to be exposed to the action of its secretions; and they affirm, that, when the galvanic influence is made to pass along the part of the nerve attached to the stomach, its effect is to restore the due action of the fibres; and, that a mechanical irritation, applied to the lower end of the divided nerves, produces a similar kind of change on the food in the stomach; from which they conclude, that the use of the par vagum, as connected with the functions of the stomach, is to bring the alimentary mass into the necessary contact with the gastric juice. These experiments were repeated in London by Mr. Cutler, under the inspection of Dr. Philip and Sir B. Brodie; but the effects of mechanical irritation of the lower part of the divided nerve did not correspond with that observed by MM. Breschet and Milne Edwards.

On the whole, the proposition of Dr. Philip,—that if the eighth pair of nerves be divided in such a manner as to effectually intercept the passage of the nervous influence, digestion is suspended,—is generally considered to be established; although it must, we think be admitted with Mr. Mayo, that the matter remains involved in great uncertainty. Analogy, in the absence of direct evidence, would suggest, that the secretion of the gastric juice should be under the presidency of the organic nervous system, and that it might persist after the section of the eighth pair, except for the general deranging influences induced by such section.

Finally, Dr. Philip found, that every diminution of the nervous influence,—the section of the medulla spinalis at the inferior part, for example,—deprives the stomach of its digestive faculty; and MM. Edwards and Vavasseur obtained the same result by the removal of a certain portion of the hemispheres of the brain, or by the injection of opium into the veins in a sufficient quantity to throw the animal into a deep coma.

Of all these theories of chymification, that of chymical action, aided by the collateral circumstances to be presently mentioned, can alone be embraced; yet, how difficult is it to comprehend, that any one secretion can act upon the immense variety of animal and vegetable substances, which are employed as food. The discovery of the acetic and muriatic acids, in the secretion, aids us a little in solving the mystery, but not much. There is not a tissue of the body, which is not dissolved if subjected long enough to the action of the former of these acids; and organic chymistry may hereafter exhibit to us some chymical agent, which has hitherto escaped detection, and which is capable of rapidly reducing to chyme all substances—both animal and vegetable—when placed under the favourable circumstances in which the gastric juice is situated in the stomach. In the existing state of our knowledge, however, regarding this wonderful and mysterious process, we might perhaps be justified in adopting the well-known pithy and laconic observation of Dr. William Hunter. "Some physiologists will have it, that the stomach is a mill; others, that it is a fermenting vat; others, again, that it is a stewpan;—but, in my view of the matter, it is neither a mill, a fermenting vat, nor a stewpan;—but a stomach, gentlemen, a stomach."

In conclusion:—Let us inquire into the various agencies to which the food is exposed during the progress of chymification. *First.* It becomes mixed with the secretions, already existing in the stomach, as well as with those excited by its presence. *Secondly.* It is agitated by the movements of the neighbouring organs, and by the peristaltic motion of the stomach itself. *Thirdly.* It is exposed to a temperature of 100° of Fahrenheit; the temperature during the ingestion of food does not rise higher: exercise elevates, whilst sleep, or rest, or a recumbent posture, depresses it. (Beaumont.)

After the food has been, for some time, subjected to these influences, the conversion into chyme commences. This always takes place from the surface towards the centre; the nearer it lies to the surface of the stomach, the more it is acted on; and that part of it, which is in contact with the lining membrane is more digested than any other; appearing as if corroded by some chymical substance capable of dissolving it.

Dr. Wilson Philip asserts, that the new food, is never mixed with the old; the former being always found in the centre, surrounded on all sides by the latter. If the old and new be of different kinds, the line of separation between them is so evident, that the old may be completely removed without disturbing the new; and, if they be of different colours, the line of demarcation can frequently be distinctly traced through the parietes of the organ, before they are laid open. Dr. Beaumont, however, affirms, that this statement is not correct; that, in a very short time, the food, already in the stomach, and that subsequently eaten, become combined. In the subject of his experiments, he invariably found, that old and new food, if in the same state of comminution, were readily and speedily united in the stomach.

The conversion of the food into chyme, it has been conceived, commences in the splenic portion, is continued in the body of the viscus, and is completed in the pyloric portion. On this point, the observations of Dr. Philip differ somewhat from those of Magendie; the former appearing to think, that chymification is chiefly accomplished in the splenic portion and middle of the stomach; whilst the latter affirms, that it is chiefly in the pyloric portion that chyme is formed; the alimentary mass appearing to pass into it by little and little, and, during its stay there, to undergo the transformation. He further affirms, that he has frequently seen chymous matter at the surface of the alimentary mass filling the splenic half; but that, commonly, it preserves its properties in this part of the stomach.

The precise steps of this change into chyme cannot be indicated. Some of the results, at different stages of the process, have been observed on animals; and pathological cases have occasionally occurred, which enabled the physiologist to witness what was going on in the interior of the stomach; but with perhaps one exception, these opportunities have not been improved. Burrows, in the 4th volume of the Transactions of the Royal Irish Academy, relates a case of fistulous opening into the stomach. The subject of the case was not seen by him, until twenty-seven years after the injury, at which time he was, to all appearance, healthy. But he was drunken, and dissipated, and the following year he died. Such a case is related by Schenckius; and Louis, in the 4th volume of the *Mémoires de l'Académie Royale de Chirurgie*, refers to similar cases that occurred to Foubert and Covillard. Helm, of Vienna, published a case of the kind, to which reference has already been made; and an interesting case occurred at the Hospital *La Charité* of Paris, which sheds some little light on the subject. The aperture, which was more than an inch and a half long and an inch broad, exposed the interior of the organ. At the admission of the female into the Hospital, she ate three times as much as ordinary persons. Three or four hours after a meal, an irresistible feeling compelled her to remove the dressings from the fistulous opening, so as to allow the escape of the food which the stomach could no longer contain, when the contents came out quickly, accompanied by more or less air. They possessed a faint smell but had neither acid nor alkaline properties; the grayish paste, of which they consisted, when diluted with distilled water, not affecting the vegetable blues. The digestion was far from complete; yet, frequently, the odour of wine was destroyed; and bread was reduced to a soft, viscid, thick substance, resembling fibrine recently precipitated by the acetous acid, and swimming in a stringy fluid of the colour of common soup. Experiments, made on this half-digested food, at the *Ecole de Médecine*, showed, that the changes, which it had undergone were an increase of gelatine; the formation of a substance like fibrine; and a considerable portion of muriate and phosphate of soda and phosphate of lime. This patient could never sleep until she had emptied her stomach, and washed it out by drinking infusion of chamomile. In the morning, it contained a small quantity of thick, frothy liquid, analogous to saliva,—which did not affect vegetable blues, with matters of greater consistence, and some completely opaque, albuminous flocculi, mingled with the liquid portion. The results of chymical experiments, on this liquid, were similar to those obtained on the analysis of saliva. But the most interesting case, in its observed phenomena, is one that occurred to Dr. Beaumont, of the United States Army, which the author had an opportunity of examining. To this case, reference has already been repeatedly made. A Canadian lad, Alexis San Martin, eighteen years of age, received a charge of buck shot in his left side, which carried away the integuments and muscles, to the size of a man's hand; fracturing, and removing the anterior half of the sixth rib, fracturing the fifth;

lacerating the lower portion of the left lobe of the lungs, and the diaphragm, and perforating the stomach.

When Dr. Beaumont saw the lad, twenty-five or thirty minutes after the accident, he found a portion of the lining, as large as a turkey's egg, protruding through the external wound, lacerated, and burnt; and, immediately below this, another protrusion, which, on inspection, proved to be a portion of the stomach, lacerated through all its coats, and suffering the food he had taken at breakfast to escape through an aperture large enough to admit the forefinger. It need scarcely be said, that numerous untoward symptoms occurred in the cicatrization of so formidable a wound. Portions of the ribs exfoliated; abscesses formed to allow the exit of extraneous substances, and the patient was worn down by febrile irritation. Ultimately, however, the care and attention of Dr. Beaumont were crowned with success, and the instinctive actions of the system repaired the extensive injury.

The wound was received in 1822, and, one year from the time of the accident, the injured parts were all sound, and firmly cicatrized, with the exception of the stomach, which continued in much the same condition as it was six months after the wound was received, the aperture being about the size of a shilling, and the food and drinks continually exuding, unless prevented by a plug, compress, or bandage.

On the 6th of June, 1823, one year from the date of the accident, the injured parts were all sound, and firmly cicatrized, with the exception of the perforation leading into the stomach, which was about two inches and a half in circumference. Until the winter of 1823-4, compresses and bandages were needed to prevent the escape of the food from the stomach. At this period, a small fold or doubling of the inner coats of the organ appeared forming at the superior margin of the orifice, slightly protruding, and increasing, in size until it filled the aperture. This valvular formation adapted itself to the opening into the stomach, so as to completely prevent the escape of the contents, when the organ was full, but it could be readily depressed by the finger.

Since the spring of 1824, San Martin has enjoyed general good health; he is active, athletic, and vigorous, eating and drinking like a healthy individual.

From the summer of 1825, Dr. Beaumont has been engaged in the prosecution of numerous experiments upon him; the results of which he has given to the world. In the winter of 1833, he was in Washington, when the author—at the time, Professor of Medicine in the University of Virginia—was politely invited to examine him for physiological purposes. Many of the results of this examination are given by Dr. Beaumont, in the publication referred to, and have already been, or will be, referred to in the present work. Dr. Beaumont's researches into the comparative digestibility of different alimentary substances belong to another department of Medical

Science, and have accordingly received attention from the author, elsewhere.*

What then, it may be asked, are the changes wrought on the food in the stomach by the gastric secretions. Dr. Prout classes them under three operations;—the *reducing*, the *converting*, and the *organizing* and *vitalizing*.

The first of these is probably the main operation. In order to decide, whether the action of the stomach in digestion is a simple solution, or a total or partial conversion, certain compounds of organization easy of detection—as *gelatine*, *albumen*, and *fibrine*—were introduced into the stomach through the fistulous opening in the subject of Dr. Beaumont's case; whilst other portions were digested *artificially* in gastric juice obtained from the same individual, the solutions presented the same appearance, and were similarly affected by reagents; and, in all cases—whether the digestion were *artificial* or *real*—the proximate principles could be thrown down in the state of *gelatine*, *fibrine*, or *albumen*, as the case might be. Farther experiments are necessary, but these, so far as they go, justify the conclusion, that the digestive process, accomplished in the stomach, is a simple solution of alimentary substances, and an admixture with the mucous secretions of that organ, and the various fluids from the supra-diaphragmatic portion of the digestive tube.

With regard to the existence of the other two gastric operations described by Dr. Prout, well-founded doubts may be entertained. To his proposition that—whatever may be the nature of the food, the general composition and character of the chyle remain always the same,—no objection can be urged but, admitting its accuracy, it by no means follows, that the conversion must be effected in the stomach, or that any organizing or vitalizing powers are exerted upon the chyme in that organ. On the contrary, it appears to us, that the whole of the changes effected on the aliment in the stomach, are of a purely physical character, so as to adapt it for the separation of the chylous portion in the digestive tube, by organs whose vital endowments and influences cannot be contested.

In proportion as the food is digested, it passes through the pylorus. As the layer, which lies next to the mucous membrane, first experiences the requisite change, and is propelled onwards by the muscular action of the organ, the portion, lying next to it, becomes subjected to the process. The gastric fluid, at the same time, penetrates, in a greater or less degree, the entire alimentary mass, so that, when the central portion comes in contact with the surface of the stomach, its conversion is already somewhat advanced. The chyme, thus successively formed, does not remain in the stomach, until the whole alimentary mass has undergone chymification; but as it is completed, it is transmitted, by the peristaltic action, through

* "On the influence of atmosphere and locality," &c. &c. constituting Elements of Hygiene, page 223, &c.

the pylorus into the duodenum. In the early stages of digestion, the passage of the chyme from the stomach is more slow than in the latter stages. At first, it is more mixed with the undigested portions of food, and, as Dr. Beaumont suggests, is probably separated with difficulty by the powers of the stomach. In the more advanced stages, as the whole mass becomes chymified, the process is more rapid, and is accelerated by the peculiar contraction of the stomach, already described.

After the expulsion of the last particle of chyme, the stomach becomes quiescent, and no more gastric secretion takes place, until a fresh supply of food is received into the organ, or some mechanical irritation is produced on its inner coat.

The time, required for the complete chymification of a meal, is stated by the generality of physiologists, to be about four or five hours. In Dr. Beaumont's case, a moderate meal of meat, with bread, &c. was digested in from three hours to three hours and a half. We believe that, in by far the majority of cases, a longer time than this is necessary; and in laborious digestions, the presence of food can be distinguished, by the eructations, for more than double the time. It is manifest, indeed, that no fixed period can be established for the production of this effect. It must vary, according to the digestive capability of the individual; the state of his general health; and the relative digestibility of the aliments employed; all which, as we have already seen, admit of great diversity.

During chymification, only a very small quantity of air is found in the stomach; sometimes, none. When met with, it is near the cardiac orifice, or at the upper part of the splenic portion. Magendie collected that which was contained in the stomach of a criminal, and had it analyzed by Chevreul, who found it to consist of oxygen, 11 parts; carbonic acid, 14; pure hydrogen, 3.55; and azote, 71.45 in the hundred.

The small quantity of air, discovered in the stomachs of animals disproves the idea of Chaussier, that we swallow a bubble of air at each effort of deglutition. If so, the stomach ought to be always inflated, especially after eating, which is not the case. Leuret and Lassaigne found the air, obtained from the stomach of a dog fed on meat, to consist of carbonic acid, 43 parts; sulphuretted hydrogen, 2 parts; oxygen, 4 parts; azote, 31 parts; and carburetted hydrogen, 20 parts. Whence these gases proceed—will be a subject for future inquiry.

In a robust individual, chymification is effected without consciousness of the process. He finds, especially if the stomach be overdistended, that the feeling of fulness and the oppression of respiration, produced by the distention of the organ, gradually disappear. It is not uncommon, however, for slight shivering or chilliness to be felt at this time; for the sensations, and mental and moral manifestations to be blunted; and for a disposition to sleep to be experienced. "This concentration of the whole vital activity," according to Adelon, "is so natural to the animal economy, that there is always danger in opposing or crossing it by any extraneous or organic influence; as by bathing, the use of medicine, violent exercise, any mental emotion, intense intellectual effort, &c." Gentle exercise would seem, however, to favour digestion. Such is the conviction of Dr. Beaumont, from his observations. In the subject of his experiment, he found the temperature of the stomach generally raised by it a degree and a half, and chymification expedited.

Where the digestion is imperfect, the signs, already mentioned, will be accompanied by the disengagement of air and consequent eructations; a sense of weight, or heat, or unusual distention in the epigastric region, &c.; but these, as well as the developement of sulphuretted hydrogen, discharged by eructation, are the products of ordinary decomposition or fermentation, and appertain to the pathological condition of the function, or to indigestion. Yet, as Magendie has remarked, it does not seem, that these laborious digestions are much less profitable than others. The food, habitually received into the stomach, contains far more nutritive matter than is necessary to supply the wants of the system; and, in the cases in question, enough chyle is always separated in the small intestine, to supply the losses, and even to add to the bulk of the body.

It has been already observed, that the chyme, first formed, does not continue in the stomach, until the whole meal has undergone chymification; but that, as soon as it has experienced the necessary changes, it passes through the pylorus into the duodenum. It would appear, that the accumulation of chyme, in the pyloric portion of the stomach, never exceeds four ounces at any one time. Magendie states, that, in the numerous experiments, in which he has had an opportunity of noticing it, he uniformly found, that, when the quantity amounted to about two or three ounces, it was permitted to pass through the pylorus into the duodenum. This passage of the chyme is effected by the peristaltic action, to which reference has been made. At the commencement of digestion, the duodenum contracts inversely, and the pyloric portion of the stomach, at the same time, drives its contents into the splenic. This movement is, however, soon followed by one in an opposite direction; and, after a time, this inverted action ceases, and the motion is altogether in one direction,—from the stomach towards the intestine.

The motion, by which the chyme is immediately sent into the duodenum, is thus effected:—the longitudinal fibres, which pass from the cardiac to the pyloric orifice, contract, and approximate the two orifices. The pyloric portion then contracts, but not so as to repel the chyme into the splenic portion; but towards the duodenum. In this manner, the chyme passes from the stomach; and, as fresh portions are formed, they are successively evacuated; the peristaltic motion becoming more and more marked and frequent, and extending over a larger portion of the organ, as chymification approaches its termination. As the chyme is discharged into the small intestine, the stomach gradually returns to its former dimensions, and situation.

6. *Action of the small intestine.*—The changes, produced upon the alimentary mass in the small intestine, are not less important than those we have already considered. These consist in a farther change, by which the chyme is converted into a substance, whence *chyle* can be extracted by the action of the chyliferous vessels or lacteals. Whether chyle be separated in the intestine, in a state fit for chyliferous absorption, or be formed by those vessels, will have to be canvassed hereafter. In common language, however, it is said to be formed in the small intestine, and the process, by which this is accomplished, is called *chylification.*

As the chyme proceeds into the duodenum, it readily finds space, until towards the end of chymification, when the intestine not unfrequently experiences considerable dilatation. The presence of the alimentary mass augments the secretions from the mucous membrane; and occasions a greater flow of the biliary and pancreatic juices. Leuret and Lassaigne found, when they applied vinegar, diluted with water, to the internal surface of the small intestine, in a living animal, that a considerable quantity of serous fluid was immediately exhaled. The same application, made to the follicles of the intestine, excited the secretion of a greater quantity of mucus; and its application to the mouths of the choledoch and pancreatic ducts caused the orifices to dilate, and a greater discharge of the bile and pancreatic juice. It is in this local manner, that many of the cholagogue purgatives produce their effect. Calomel exerts its agency on the upper part of the intestinal canal more especially; and the irritation it induces in the mucous membrane, at the mouth of the ductus communis choledochus, is propagated along the ducts to the liver, the secretion of which is thus augmented,—but not by any specific action exerted on the liver, as has been often imagined. As the chyme is acid, it necessarily induces the same effects as the acid employed in the experiments of Leuret and Lassaigne.

The chyme does not remain so long in the intestine, as the food does in the stomach. The successive arrival of fresh portions propels the first onwards; and the same effect is induced by the peristaltic action of the intestines,—an involuntary, muscular movement of an irregular, undulatory, oscillatory or vermicular character, which consists in an alternate contraction and dilatation of the organ, proceeding generally from above to below, so as to propel the chyme downwards. When the chyme reaches any point of the intestine, its contact excites the contraction of the circular fibres of the part; so that it is sent forwards to another part of the canal; the circular fibres of which contract, whilst the former are relaxed; and this occurs successively through the whole extent of the intestines. The longitudinal fibres, by their contraction, shorten the intestine, and in this manner meet the chyme, so as to facilitate its progress; but their effect cannot be considerable. When digestion is not going on, the peristaltic action occurs only at intervals; always slowly and irregularly; and, perhaps, as has been suggested, only when a quantity of mucous secretion has collected on the inner coat of the intestine sufficient to provoke it. During digestion, it is much more energetic and frequent, and is more marked in the duodenum and small intestine than in the large; occurring not continuously, but at intervals, as the chyme arrives and excites it. When the small intestine is surcharged, it may take place in several parts of the canal at once; and, at times, the action is inverted.

The secretions, poured out into the intestinal canal, lubricate it, and facilitate the progress of the chyme. This is, also, aided by the free, and floating condition of the intestine; and by the agitation from the diaphragm and abdominal muscles in respiration. Yet the course of the chyle along the small intestine is slow. The chyme is not transmitted from the stomach continuously; and the peristaltic action of the intestines occurs only at intervals. Moreover, owing to the convolutions of the intestinal canal, the chyme must, in many cases, proceed against its own gravity; and it must be retarded by the numerous valvulæ conniventes, which bury themselves in the chyme, when the canal is contracted by the action of the circular fibres. All these circumstances must cause the chyme to proceed slowly along this part of the canal,—a point of some importance, when we reflect that a very essential change is effected on it through the influence chiefly of the bile and pancreatic juice, and that its nutritive portion is here absorbed. In the duodenum, the course of the chyme is slow. In the jejunum it is more rapid, whence the name,—which indicates, that it is almost always found empty: in the ileum it is again slower, on account of the greater consistence the matter has acquired, by the absorption of its chylous portion. Whilst the food is in progress along the small intestine, it experiences that change in its physical properties, which enables the chyle to be separated from it by absorption; and, as soon as this change is produced, the chyle is taken up from it. These two actions have been termed respectively *chylification* and *the absorption of chyle;* although by some the former term has been applied to both processes.

Above the point, at which the common choledoch and pancreatic ducts open into the duodenum, no change is observable in the chyme. It preserves its colour, semi-fluid consistence, sour smell, and slightly acid taste; having been simply mixed with the exhaled and follicular secretions of the lining membrane. But, immediately after it has passed the part, at which the hepatic and cystic bile and the pancreatic juice are poured into the intestine, it assumes a different appearance, its colour is found to be changed; and it becomes yellowish; of a bitter taste; its sour smell diminishes; and chyle can now be separated from it by the lacteals. Accordingly, at this part of the canal, chyliferous vessels are first perceptible.

The change, effected upon the chyme in the small intestine, is probably,—like that produced on the food in the stomach,—of an entirely physical character. The chyle itself, we shall endeavour to show hereafter, is formed by an action of elaboration and selection exerted by the chyliferous vessels. No difference is observable between the chylous and excrementitious portion of the chyme, in any part of the small intestine; nor can it be separated by pressure or any other physical process. Magendie, indeed, has affirmed, that if the chyme proceeds from animal or vegetable substances, which contain fat or oil, irregular filaments are observed to form, here and there, on the surface,—sometimes of a flat, at others, of a round shape,—which speedily attach themselves to the surface of the valvulæ, and appear to be *brute chyle;* but this is not observed when the chyle proceeds from food, which does not contain fat. In this case, a grayish layer, of greater or less thickness, adheres to the mucous membrane, and appears to contain the elements of the chyle. Leuret and Lassaigne also state, that if an animal be opened, whilst digestion is going on,—on the surface of the chyme between the pylorus and the orifice of the ductus communis choledochus, a substance, of a grayish-white appearance, homogeneous, dense, fluid and acid, is perceived applied to the villi of the intestine. Neither of these, however, is chyle. It is merely the substance whence chyle is obtained by the action of the chyliferous vessels.

The fact, mentioned by Magendie,—regarding the appearance of irregular filaments, when animal or vegetable substances, containing fat or oil, have been taken as a diet,—has been the occasion of other erroneous deductions of a pathological character. Frank asserts, that he was requested to see a prince, who was attacked with epilepsy. His physician,—a respectable old practitioner,—assured Frank that he could make his patient void at pleasure thousands of filiform worms. As he was unable to define either the genus or species of these worms,—the quantity of which, from his account, seemed to be prodigious,—Frank requested to be a witness of the phenomenon. The physician administered a dose of castor oil, which produced numerous evacuations, containing thousands of whitish filaments, similar to small eels; but, on an attentive examination of these pretended worms, they were found to consist entirely of the castor oil, in a state of coagulation.

The change, effected in the small intestine, is probably of a chymical nature, yet its essence is impenetrable. It has, accordingly, been conceived to be organic and vital. The same remarks are applicable here, as were indulged on the supposed organic and vital action of the stomach, exerted in the formation of chyme. The agents of this conversion are;—the fluids secreted from the mucous membrane of the small intestine, and the biliary and pancreatic juices, aided by the temperature of the parts, and the peristaltic action. Haller was of opinion, that the first of these is a principal agent. Reflecting on the extensive surface of the small intestine, on the number of arteries, distributed to the organ, and on the size of these arteries, he asserted, that the lining membrane of the intestine, at the time of chylification, secretes a juice, which he estimated at the enormous quantity of eight pounds in the twenty-four hours. To this he gave the name—*succus intestinalis*—and assigned it as important a part in chylification, as he attributed to the gastric juice in chymification.

It is probable, however, that the fluids, secreted by the mucous membrane of this portion of the canal, resemble those of the rest of the intestinal mucous membrane; and that their main function is that of lubricating the intestine, and of still farther diluting the chymous mass. Leuret and Lassaigne endeavoured to procure some of them, by making animals, whilst fasting, swallow small sponges, enveloped in fine linen, and killing them twenty-four hours afterwards. Some of these sponges had not gone farther than the stomach, and were filled with gastric juice; others, which had reached the small intestine, had imbibed the *succus intestinalis*, which was more yellow, and manifestly less acid than the other. On attempting to dissolve, artificially, a crumb of bread, in both of these juices, they discovered, that the gastric juice communicated a sour smell to the bread; but that the intestinal juice allowed the bread to be precipitated, and dissolved no part of it.

From this experiment, it has been concluded, that the succus intestinalis is not the great agent of chylification. This deduction is probably correct; but no weight can be placed upon results obtained in so unsatisfactory a manner; for it is obvious, that no certainty could exist as to the identity between the gastric and intestinal juices, and the fluids respectively found in the different sponges.

We have strong reason for believing, that, even if food should escape the action of the stomach, it is capable of being digested in the small intestine. This may be owing to some of the true gastric juice passing into the intestinal canal, and impregnating it; or it may be produced by some similar secretion from follicles seated there. The lining membrane of the small intestine possesses the property of coagulating milk; and pathological cases occur, in which the stomach is, to all appearance, completely disorganized, yet the patients survive so long as to compel us to presume, that digestion must have been effected elsewhere than in the stomach.

Magendie placed a piece of raw meat in the duodenum of a healthy dog. At the expiration of an hour, it had reached the rectum, and its weight was found to be but slightly diminished; the only change appeared to be at its surface, which was discoloured. In another experiment, he fixed a piece of muscle, with a thread, so that it could not pass out of the small intestine. Three hours afterwards, the animal was opened. The piece of meat had lost about half its weight. The fibrine was especially attacked; and what had resisted,—which was almost wholly cellular,—was extremely fetid. In some experiments by Voisin, aliment was introduced into the small intestines of animals,—in the one case masticated and mixed with saliva, and in the other without any preparation. In a few hours in the first instance, and after a longer period in the second, the food was as completely chymified as if the process had taken place in the stomach. The same experiments were repeated upon animals in which the pylorus had been secured by a ligature, and with similar results. One of the animals lived for a month after the pylorus was tied, being nourished for that period by food introduced into the duodenum.

These facts sufficiently show, that a solvent property is exerted in the small intestine.

The biliary and pancreatic juices are usually esteemed the great agents in chylification. We have already remarked, that the chyliferous vessels do not begin to appear above the part at which these juices are poured into the duodenum; that, in the rest of the small intestine, they are less and less numerous as we recede from the duodenum; and that the chyme does not exhibit any marked change in its properties, until after its admixture with those fluids. Direct experiments have, also, been made for the purpose of testing the use of the bile in digestion. Sir Benjamin Brodie tied the ductus communis choledochus in young cats, so as to prevent both the hepatic and cystic bile from reaching the intestine. He found that chylification was interrupted, and that there were neither traces of chyle in the intestines nor in the chyliferous vessels. The former contained only chyme, similar to that of the stomach, which became solid at the termination of the ileum; and the latter, a transparent fluid, which appeared to be a mixture of lymph and of the more liquid portion of the chyme. Mr. Mayo likewise found, that when the ductus communis choledochus was tied in the cat or dog, and the animals killed at various intervals after eating, there was no trace whatever of chyle in the lacteals.

Magendie, however, repeated these experiments on adult animals, and with dissimilar results. The greater part died of the consequences of opening the abdomen, and of the operation required for tying the choledoch duct. But in two cases, in which the animals survived some days, he discovered that digestion had persisted; that white chyle had been formed, and stercoraceous matter produced. This last had not the usual colour, which, as he remarks, is not surprising, as it contained no bile. The experiment was likewise repeated by MM. Leuret and Lassaigne, and with results similar to those obtained by Magendie. In the duodenum and jejunum, a whitish chyme adhered to the parietes of the organ; and, in the thoracic duct, a fluid existed, of a rosy-yellow colour, which afforded, on analysis, the same constituents as chyle; although the animals, which were the subjects of the operations, had been kept, for some time, without food.

The experiments of Tiedemann and Gmelin on this subject, were marked by the usual care and accuracy of those observers. They remarked, that the animals were attacked with vomiting, soon after the operation, and afterwards with thirst and aversion for food; on the second or third day, the conjunctiva became yellow, the evacuations chalky, and very fetid, and the urine yellow. Some of the animals died: others were killed; of the latter, some had previously recovered from the jaundice, owing to a singular recuperative phenomenon, noticed by Dr. Blundell and Sir B. Brodie in their experiments—the re-establishment of the choledoch duct, by the effusion of lymph around the tied part, and the subsequent dropping off of the ligature. Like Sir B. Brodie, Mayo, Leuret and Lassaigne, and Voisin, they observed that chymification went on as in the sound animal. The thoracic duct and chyliferous vessels, in animals fed recently before death, always contained an abundant fluid, which was generally of a yellowish colour. It coagulated like ordinary chyle; the crassamentum acquired the usual red colour, and the only difference between it and the chyle of a sound animal was, that after tying the choledoch duct it was never white. The reason of the difference, they conceived to be, that the white colour is owing to fatty matter taken up from the food by means of the bile, which possesses the power of dissolving fat, and may probably, therefore, aid in effecting its solution in the chyle at the mouths of the chyliferous vessels. Sir Benjamin Brodie, and Mr. Mayo are considered to have been misled by the absence of the white colour, which the chyle usually possesses, but which it wants in ordinary digestion, if the food does not contain fatty matter. The experiments of Dr. Beaumont showed, that oil undergoes but little change in the stomach, and that bile is probably necessary to give it the requisite physical constitution, in order that chyle may be separated from it. Professors Tiedemann and Gmelin restricted the agency of the bile in chylification to accomplishing the solution of the fatty matter, and to azotizing or animalizing food that does not contain azote.

The experiments of M. Voisin equally show, that the ligature of the choledoch duct does not prevent the formation of chyle, provided the passage of the pancreatic fluid is not at the same time prevented. In a number of dogs, a ligature was applied so as to completely prevent the entrance of the bile into the intestine. Two lived three months after the experiment; three, six weeks; and five died shortly after the ligature was applied. In no instance, did death appear to be owing to the suspension of digestion or assimilation. Almost all the dogs had begun to eat, and, in the majority, food was found in the duodenum perfectly chymified; and well elaborated chyle in the chyliferous vessels.

It would appear, therefore, that the bile although important, is not an essential agent in the digestion effected in the duodenum.

As to the mode in which the biliary and pancreatic fluids act on the chyme, we have only conjectures to guide us. MM. Tiedemann and Gmelin suggest, that the soda of the bile unites with the muriatic and acetic acids of the chyme; whilst, at the same time, the latter precipitates the mucus of the bile, its colouring principle and resin; which are evacuated with the excrements. The majority of physiologists believe, that the bile is divided into two parts, by the action of the chyme; the one, which contains the alkali, the salts, and a part of the animal matter, uniting with the chyle; the other, which contains the coagulated albumen, the coloured, concrete, acrid, and bitter oil, uniting with the fæces, and being discharged with them.

According to this view, the action of the bile would be entirely chymical; a part would be recrementitial or taken up again into the system; and a part excrementitial, giving to the excrements their smell, colour, and, according to some, the necessary stimulating property for exciting the flow of the intestinal fluids, and for soliciting the peristaltic action of the intestines so as to produce their evacuation. It is more than doubtful, however, whether the bile has any such influence as the last. It is a law in the economy, that no secretion irritates the part over which it passes or is naturally destined to pass, unless such part be in a morbid condition: and, moreover, were it otherwise, the mucous membrane of the intestine would be soon accustomed to such stimulation; and, consequently, the effect be null. MM. Tiedemann and Gmelin farther suggest, that from the abundance of highly azoted principles, which the bile contains, it probably contributes to animalize those articles of food, that do not contain azote; and that it may tend to prevent the putrefaction of the food in its course through the intestines, because, when it is prevented from flowing into them, their contents appear much farther advanced in decay than in the healthy state.

We are not better instructed with regard to the precise uses of the pancreatic juice; although many have been assigned to it, which, being founded in utter ignorance of its nature and properties, it would be a waste of time to notice. Tiedemann and Gmelin affirm, that it yields to the chyme the richly azoted principles, which enter into its composition; and, consequently, aids in its assimilation. In testimony of this, they remark, that the pancreas is larger in herbivorous than in carnivorous animals; and that, in proportion as the chymous matter proceeds along the intestinal canal, it exhibits itself less rich in albumen and other azoted matters, which have probably been abstracted from it by absorption.

Marcet discovered in the chyme of the small intestine a notable developement of albumen; which was first perceptible at a few inches from the pylorus, and did not exist in the large intestine, and Tiedemann and Gmelin found that in animals, which had swallowed pebbles while fasting, there was, in the intestinal contents, more albumen than the pancreatic juice could account for. Albumen must consequently be either developed from the food or secreted from the mucous membrane. The latter is more probable.

The influence of the temperature of the interior of the intestine, and of the peristaltic motion, on chylification, can only be looked upon as accessory and indirect.

Whilst the chyme is passing through the small intestine, it is subjected to the action of the chyliferous vessels, which extract from it the nutritious part, called *chyle*,—the fluid especially destined for the renovation of the blood. How this is accomplished will be treated under the head of *absorption*.

In proportion as this absorption is effected, the chyme changes its apparent properties. In the commencement of the jejunum, it is the same as in the duodenum; but, lower down, the grayish layer, which existed at its surface, is observed to gradually disappear. It assumes greater consistence; its yellow colour becomes more marked; and, in the ileum, it has a greenish or brownish tint; and becomes less and less acid; until, at the lower part of the small intestine, it seems to be the useless residue of the alimentary matter, and of the various secretions from the digestive apparatus. It is now merely excrementitious matter or fæces, although not yet possessing the odour.

During the formation of chyle, gases are almost always present in the small intestine. These were first examined by Jurine; but chymical analysis was by no means as perfect at that day as it is now; Magendie and Chevreul have more recently analyzed those, which they found in the small intestines of three criminals; all of whom were young and vigorous. One of these was twenty-four years of age. He had eaten, about two hours before execution, bread and *gruyère* cheese; with red wine for drink. The gas of the small intestines consisted of oxygen, 0.00; carbonic acid, 24.39; pure hydrogen 55.53; azote, 20.08.

The second of the criminals was twenty-three years old. In other respects, he was circumstanced like the last. The gas, in his case, contained:—oxygen, 0.00; carbonic acid, 40.00; pure hydrogen, 51.15; and azote, 8.85.

The third was twenty-eight years old. He had eaten—four hours before execution—bread, beef, and lentils; and had drunk red wine. The gases contained:—oxygen, 0.00; carbonic acid, 25.00; pure hydrogen, 8.40; and azote, 66.60.

These gases might originate in various ways. They might, for example, proceed from the stomach with the chyme. There is this objection, however, to that view;—that the air in the stomach contains oxygen and very little hydrogen; whilst a considerable quantity of the latter gas is almost always found in the small intestine, and never any oxygen.

Again, they might be secreted by the mucous membrane of the intestine. So far as we know, however, carbonic acid and azote are alone exhaled from the tissues. We would still have to account for the existence of the hydrogen.

Lastly, they might arise from the reaction of the elements of the chyme upon each other, and this is the most probable origin. Magendie has frequently seen bubbles of gas escaping from the chymous mass, situated between the mouth of the ductus communis choledochus and the ileum; but never from that of the ileum, from the upper part of the duodenum, or stomach; and he affirms, that Chevreul found, in prosecuting some experiments not yet published, that, when the mass, obtained from the small intestine, was suffered to ferment, for some time, in a stove, at the temperature of the body, precisely the same gases were obtained as those met with in the small in estine.

When the food has attained the lower part of the ileum, the process of chylification has been accomplished, and the residuary matter is transmitted into the large intestine, by the same peristaltic action, which has been so often described. The movement, however, recurs very irregularly and at long intervals. On the living animal, it can be rarely perceived; but may be noticed on one recently killed. It appears to have no coincidence with that of the pylorus.

7. *Action of the large intestine.*—The large intestine acts as a reservoir and excretory canal for the fæces. The residue of the alimentary matter is sent on, through the valve of Bauhin, by the peristaltic action of the ileum. This valve, we have seen, is so situated, at the point of union between the ileum and cæcum, as to permit a free passage from the former to the latter, but to prevent its return. The chymous mass is, also, as yet, sufficiently soft to pass readily; and the quantity of mucus, poured out from the lining membrane, facilitates its course.

When it has reached the large intestine, it first accumulates in the cæcum; which being cellular or pouched, like the colon, necessarily detains it for some time. In proportion, however, as the cæcum becomes filled, the same peristaltic action is established as that which occurs in the small intestine, and the matter is sent on into the colon, the cells of which are successively filled; first, those of the ascending, and then those of the transverse and descending colon, as far as the annulus or commencement of the rectum.

The whole of its progress through the large intestine is very slowly accomplished. Independently of the pouched arrangement, which retards it, a part of the colon ascends, so that the fæcal matter must proceed contrary to its gravity. It becomes, moreover, more and more inspissated, in its progress towards the outlet; and the peristaltic action recurs at greater intervals, than at the upper portions of the tube.

The importance of such a reservoir as the large intestine is obvious. Without it, we should be subjected to the inconvenience of evacuating the fæces incessantly

Before the excrementitious matter reaches the large intestine, it has not the fetid odour peculiar to human fæces; but it acquires this after having remained in it for a short time. The brownish-yellow colour becomes deeper; but its consistence, smell, and colour vary considerably, according to the character of the alimentary matter; the mode and degree in which chymification and chylification have been accomplished; the habit of the individual, &c. &c.

The fæcal matter, as we find it, consists of the excrementitious part of the food, as well as of the juices of the upper part of the canal, which have been subjected to the digestive process; of the secretions, poured out from the lower part of the intestine; and, also, of those substances, which have escaped the digestive actions of the stomach and small intestine, and are often perceptible in the evacuations.

The peculiar fæcal impregnation is probably dependent upon a secretion from appropriate follicles, situated towards the extremity of the small, and in the large, intestine; and we can thus understand, if we take into consideration the digestion of the different secretions, why fæcal evacuations may exist, when the individual has not eaten for some time, or has taken but little nourishment.

Some physiologists have believed that chylification takes place even in the large intestines, and that chylous absorption is more or less effected there. Viridet asserted, that the cæcum is a second stomach, in which a last effort is made to separate from the food the digestible and soluble portions it still contains. In herbivorous animals, according to him, an acid, solvent, fluid is secreted in it. MM. Tiedemann and Gmelin, two of the latest writers on digestion, seem to admit this fact; and they likewise think, that the fluid, secreted by the inner membrane of this intestine, assists in the assimilation of the food by means of the albumen it contains, and that the fæcal matter is formed in this intestine. The fact of the separation of chyle in the cæcum and colon is proved by the experiments of Voisin, which consisted in introducing food into these intestines after the ileo-cæcal valve had been closed by ligature.

The physical characters of the fæces have already been described. When extruded, they have the shape of the large intestine, or of the aperture, through which they are evacuated. If, therefore, the shape of either of these be modified, that of the excrement is so correspondently. In stricture of the colon, especially about the sigmoid flexure, and of the rectum, the fæces are squeezed through the constricted portion, and often evacuated in the shape of ribands. The quantity must, of course, vary, according to circumstances, and cannot be rigidly estimated. Approximately, they have been presumed to be, in the adult male, from a quarter to half a pound in the twenty-four hours, the evacuation being usually made once only in this time.

The biliary secretion appears to modify greatly the appearance of the fæces. If, as in cases of jaundice, it is prevented from flowing into the intestine, the evacuations are clay-coloured. Adelon affirms, that, under such circumstances, they are more frequent. This is not the result of our experience, nor does it appear to be deduced from his own; as, a few pages before, he remarks, "it is certain, that if the bile does not flow, the excrements are dry, devoid of colour, and there is constipation."

On the other hand, if the bile flows in too great quantity, the fæces are darker coloured. It is doubtful, whether the varying quantity of the biliary secretion has much influence on the number of the evacuations, unless the canal, through which it has to pass, is in a morbid condition. Many of the appearances in the fæces, which are conceived to be owing to a morbid condition of the biliary secretion, are the effect of admixture with the products of morbid changes in the stomach or intestines. In elucidation of this, it may be observed, that the green evacuations of children are often referred to some pathological condition of the biliary secretion; whereas the colour is commonly owing to unusual formation of acid in the stomach, the admixture of which with healthy bile produces the colour in question.

The chymical properties of the fæces have been repeatedly examined. They must, of course, vary according to the nature of the food, its quantity, the kind of digestion, &c. They are different in each animal species. Those of the herbivora contain less animal matter than those of the carnivora and omnivora; and the agriculturist is well aware, that the excrements of all animals are not equally valuable as manure. The dung of the pigeon is alkaline and caustic; and, hence, has been employed in tanning for softening skins. The excrement of dogs, which have fed only on bones, is white, and appears to be almost wholly composed of the earthy matter of bone. It has not, however, been examined by modern chymists. This white excrement is the *album græcum*, *cynocoprus*, *spodium Græcorum*, *album canis*, or *stercus caninum album* of the older writers. It was formerly employed as a discutient to the inside of the throat in quinsies, but is now justly discarded.

Vauquelin, on comparing the nature and quantity of the earthy parts of the excrements of fowls, with those of the food on which they had subsisted, arrived at some results which are of deep interest to the physiologist. He found, that a hen devoured, in ten days 11111.843 grains troy of oats. These contained of phosphate of lime, 136.509 grains; and of silica, 219.548 grains; in the whole, 356.057 grains.

During these ten days she laid four eggs, the shells of which contained 98.779 grains of phosphate of lime and 58.494 grains of carbonate of lime; and passed 185.266 grains of silica. The fixed parts, thrown out of the system, during the ten days, amounted to:—

Phosphate of lime - - -	274.305 grains.
Carbonate of lime - - -	511.911
Silica, - - - - -	185.266
Given out, - - - -	971.482
Taken in, - - - -	356.057
Surplus, - - - -	615.425

The quantity of fixed matter, therefore, given out of the system in ten days, exceeded the quantity taken in, by this last amount.

The phosphate of lime, taken in, amounted to	136.509 grains.
That given out, to - - - - -	274.305
	137.796

There must, consequently, have been formed, in this fowl, 137.796 grains of phosphate of lime, besides 511.911 grains of the carbonate. The inferences, deduced from these experiments, were, that lime, and perhaps also phosphorus, is not a simple substance, but a compound, and formed of ingredients, which exist in oats, water, or air, the only substances to which the fowl had access; and that silica must enter into its composition, as a part had disappeared. Before, however, we adopt these conclusions, the experiments ought to be more than once repeated. The chicken should be fed on oats some time before the excrements and shells are subjected to analysis; as the carbonate of lime and the excess of phosphate of lime, detected on analysis, might have proceeded from the food, as well as from the earthy matters previously swallowed. Care should also be taken, that it has no access to any calcareous earth; and it must be certain, that it has not diminished in weight; as, in such case, the calcareous earth may have been supplied from its own body. These precautions are the more requisite, seeing, that experiments appear to have shown, that certain birds cannot produce eggs unless they have access to calcareous earth.

We have, however, some very remarkable instances of chymical changes, in the mysterious actions, more immediately concerned in the decomposition and renovation of the frame; or, in what has been abstractedly termed—the function of nutrition. Dr. Henry has announced, that the following substances have been satisfactorily proved to exist in healthy urine;—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatine, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluate of lime, muriate of soda, phosphate of soda, phosphate of ammonia, sulphur, and silex;—yet we have no proof, that these substances are obtained from any other source than the food; and some of them are, with difficulty, obtained any where. Every one of them is necessary for the constitution of the urine; and many must be formed by a chemical union of their elements under the vital agency. Some are met with in the animal body exclusively.

Berzelius found, in 100 parts of human fæces:—water, 73.3; unaltered residue of animal and vegetable substances, 7.0; bile, 0.9; albumen, 0.9; peculiar extractive matter, 2.7; substance, formed of altered bile, resin, animal matter, &c. 14; and salts, 1.2. Seventeen parts of these salts contained, carbonate of soda, 5; muriate of soda, 4; sulphate of soda, 2; ammoniaco-magnesian phosphate, 2; phosphate of lime, 4.

The excrements have likewise been examined by Leuret and Lassaigne, and by Prout and others; but none of the analyses have shed much light on the physiology of digestion.

In the large intestine, gases are also met with, along with the fæces. These were examined by Magendie and Chevreul, in the three criminals already referred to. In the first, 100 parts of the gas contained;—oxygen, 0.00; carbonic acid, 43.50; carburetted, and some traces of sulphuretted, hydrogen, 5.47; azote, 51.03. In the second, oxygen, 0.00; carbonic acid, 70.00; pure and carburetted hydrogen, 11.60; azote, 18.40. In the third, the gas, found in the cæcum, was analyzed separately from that of the rectum. These were found to contain respectively in 100 parts:—

	Cæcum.	Rectum.
Oxygen, - - - - - -	0.00	0.00
Carbonic acid, - - - - -	12.50	42.86
Pure hydrogen, - - - -	7.50	
Carburetted hydrogen, - - -	12.50	11.18
Azote, - - - - - -	67.50	45.96
Traces of sulphuretted hydrogen, -	Some.	Some.
	100.00	100.00

The results accord with those of Jurine, obtained long ago, as regards the nature of the gases: but they do not accord with what he says relating to the carbonic acid; the quantity of which, according to him, goes on decreasing from the stomach to the rectum. The analyses, given, show that the proportion increases instead of decreasing.

Concerning the origin of these gases, the remarks made on those of the small intestine are equally applicable here.

When the fæcal matter has accumulated to the necessary extent in the rectum, its expulsion follows; and to this function the term *defecation* has been appropriated.

The fæces collect gradually in the large intestine, without any consciousness on the part of the individual. Sooner or later, the desire or want to evacuate them arises. This is usually classed among the internal sensations or desires. It is, however, properly, of a mixed character. That it is not always in a ratio with the quantity of fæces is shown by the fact, that, occasionally, the intestine will be filled without the want arising; and, if the fæces be unusually thin or irritating, the desire is developed, when an extremely small quantity of matter is present,—as in cases of tenesmus.

The period, at which the desire returns, is variable, according to the quantity and character of the food employed, as well as to the habit of the individual. Whilst the generality of persons evacuate the bowels, at least once in the day,—and this usually at a period regulated by custom,—others will pass a week or two without any alvine discharge, and yet be in perfect health. Nay, some of the collectors of *Cas rares* have affirmed, on the authority of Rhodius, Panarolus, Salmuth, and others, that persons may continue in health, with the bowels moved not oftener than once a month, three months, half a year, two years, and even seven years, without serious mischief!

When the desire has once exhibited itself, it generally persists until the fæces are expelled. Sometimes, however, it disappears and recurs at an uncertain interval; and, if again resisted, it becomes the source of great pain, and ultimately commands implicit obedience. That the pressure and irritation of the fæces develope the sensation is evidenced by the circumstance, that the relief experienced, when the desire is urgent, is usually accompanied by a manifest return of the fæcal matters from the sigmoid flexure into the colon.

In evacuating the fæces the object to be accomplished is,—that the contents of the large intestine shall be pressed upon with a force superior to the resistance, presented by the annulus or upper extremity of the contracted rectum, and by the muscles of the anus. The contraction of the rectum is generally insufficient to effect this last object, notwithstanding the considerable thickness of its muscular layer. In cases, however, of great irritability of the rectum, the sphincter is incapable of resisting the force developed by the proper muscular fibre of the rectum.

Under ordinary circumstances, the aid of the diaphragm and abdominal muscles is invoked, and it is chiefly through these muscles, that volition influences the act of defecation,—suspending, deferring, or accelerating it as the case may be. After a full inspiration, the muscles, which close the glottis, and the expiratory muscles,—especially those on the anterior part of the abdomen,—contract simultaneously. The air cannot escape from the lungs; the diaphragm is depressed upon the abdominal viscera, and the whole thorax presents a resisting body; so that all the expiratory power of the abdominal muscles bears upon the viscera, and presses them against the vertebral column. In this way, considerable force is exerted upon the contents of the colon and rectum; the resistance of the sphincter,

—already diminished by the direct exertion of volition,—is surmounted; it yields and the fæces are extruded. The levator ani and ischio-coccygeus, aided by the transversus perinei muscles, support the anus during the propulsory efforts, and restore it to its place, after these efforts have ceased.

Whilst the *straining* is effected by the diaphragm and abdominal muscles, the longitudinal muscular fibres of the rectum contract, so as to shorten the intestine, and, consequently, the space over which the fæces have to pass. On the other hand, the circular fibres contract, from above to below, so as to propel the excrement downwards, and to cause the mucous membrane to extrude, and form a ring or *bourrelet*, like that which occurs at the cardiac orifice of the stomach, when the food is passing from the œsophagus into that organ. If this extrusion occurs to a great extent it constitutes the disease, called *prolapsus ani.*

Of late, Dr. O'Beirne has directed his attention to the subject of defecation; and, guided by the following facts and arguments;—that great irritation would be produced in the sphincter ani, and in the bladder, if the fæces descended readily into the rectum;—that the difficulty experienced in throwing up an injection is inconsistent with the idea of the rectum being open, and proves that it is firmly contracted and closed;—that when the surgeon has occasion to pass his finger up the rectum, he rarely encounters either solid or fluid fæces;—that the two sphincter muscles of the anus are considerably weakened in certain diseases, and divided in certain operations, yet it rarely happens, that the power of retaining the fæces is destroyed;—that on passing a stomach tube to the height of half an inch up the rectum, in a number of healthy persons, it was found, that nothing escaped, and that it could be moved about freely in a space, which, on introducing the finger, was ascertained to be the pouch of the rectum; but that from the highest part of the pouch to the upper extremity of the gut—generally a distance of from six or seven to eight inches—the tube could not be passed upwards without meeting with considerable resistance, and using a degree of force to mechanically dilate the intestine, which was plainly felt to be contracted so as to leave no cavity for this extent;—that when the instrument reached, in this way, the uppermost point of the rectum, the resistance to its passage upward was felt to be sensibly increased, until, at length, by using a proportionate degree of pressure, it passed rapidly forward—as if through a ring—into a space in which its extremity could be moved with great freedom, and as instantly a rush of flatus, of fluid fæces, or of both, took place through the tube;—that in every instance, where the tube presented the least appearance of fæces after being removed, this appearance was confined to that portion, which had entered the sigmoid flexure:—led by these and other facts, Dr. O'Beirne concludes; that, in the healthy and natural state, all that part of the rectum above its pouch, is at all times, with the single exception of a few minutes previous to the evacuation of the bowels, firmly contracted, and perfectly empty, at the same time that the pouch itself as well as the sigmoid flexure of the colon, are always more or less open, and pervious;—and that the sphincter ani muscles are merely subsidiary agents in retaining the fæces.

When the fæces are firm, considerable muscular effort is necessary to expel them; but, when they are of a softer consistence, the contraction of the rectum is sufficient.

The air, contained in the intestinal canal, readily moves about from place to place, and speedily reaches the rectum by the peristaltic action alone. Its expulsion, however, is commonly accomplished by the aid of the abdominal muscles, when it issues with noise. If discharged, by the contraction of the rectum alone, it is generally in silence. Children are extremely subject to flatulence, but in the adult it is not common. Some kinds of diet favour its production more than others, especially in those of weak digestive powers, of which its undue evolution is, indeed, generally an indication. The leguminous and the succulent vegetables, in general, belong to this class. Where digestion is tardily accomplished, they undergo fermentation, and the disengagement of gas is the consequence. Too often, however, the disgusting habit of constantly discharging air streperously from the bowels is encouraged, rather than repressed; and there are those, who are capable of effecting the act almost as frequently as they attempt it.

The noise, made by the air, as it passes backwards and forwards in the intestinal canal, constitutes the affection called *borborygmus*.

So much for the digestion of solid food.

II. *Digestion of Liquids.*

In examining into the digestion of liquids, we shall follow the same order as that observed in the digestion of solids; but as many of the acts are accomplished in precisely the same manner, it will not be necessary to dwell upon them.

1. *Thirst.*—Thirst or the desire for drink is an internal sensation; in its essence resembling that of hunger, although not referred to precisely the same organs. It arises from the necessities of the system, from the constant drain of the fluid portions of the blood, and is instinctive or essentially allied to organization.

The sensation differs in different individuals, and is rarely alike in the same person. Usually, it consists of a feeling of dryness, constriction, and heat in the back part of the mouth, pharynx, œsophagus, and occasionally in the stomach; and, if prolonged, redness and tumefaction of the parts supervene, with a clammy condition of the mucous and follicular—and diminution and viscidity of the salivary—secretions. These phenomena are described as being accompanied by restlessness, general heat, injected eyes, disturbed mind, acceleration of the circulation, and short breathing, the mouth being frequently and largely open, so as to admit the air to come in contact with the irritated parts, and thus to afford momentary relief.

Thirst is a very common symptom of febrile and inflammatory diseases in which the fluid is desired, in consequence of the local relief it affords,—especially when cold,—to the parched and heated membrane of the alimentary canal. It is also developed by circumstances exterior to us; as in summer, when the body sustains considerable loss of fluid, as well as in those diseases—as dropsy, diabetes, &c.—which produce the same effect.

There are many other circumstances, however, that excite it;—as long speaking or singing; certain kinds of diet—the saline and spicy, for example—and especially the habit, acquired by some, of frequently drinking. Whilst such individuals may need several gallons a day, to satisfy their wants;—others, who have, by resistance, acquired the habit of using very little liquid, will be enjoying good health and not experiencing the slightest inconvenience from its privation; so completely are we, as regards the character and quantity of our aliment, the creatures of habit. This privation, it is obvious, cannot be absolute or pushed beyond a certain extent. There must always be fluid enough taken to administer to the necessities of the system.

As in the production of every internal sensation, three acts are required in accomplishing that of thirst:—impression, conduction and perception. The last, as in every similar case, is effected by the brain, and the second by the nerves passing between the part impressed and that organ.

The act of impression—its seat and cause—will alone arrest our attention; we shall find, that we are still less instructed on these points, than on the physiology of hunger. Even with regard to the seat of the impression, we are in a state of uncertainty. It appears to be chiefly in the back part of the mouth and fauces; but, whether primarily there, or produced by sympathy with the condition of the stomach, is by no means clear. The latter opinion, however, appears the more probable. In a remarkable case, published by Dr. Gairdner of Edinburgh, it was found impracticable to allay the thirst, by merely supplying the mouth, tongue and fauces with fluid. A man had cut through the œsophagus. An insatiable thirst arose; several pailfuls of water were swallowed daily, and discharged through the wound, without allaying the thirst; but, on injecting water, mixed with a little spirit, into the stomach, it was soon quenched. That the sensation is greatly dependent upon the quantity of fluid circulating in the vessels, is shown by the fact, mentioned by Dupuytren, that he succeeded in allaying the thirst of animals, by injecting milk, whey, water or other fluids into the veins; and Orfila states, that in his toxicological experiments, he frequently allayed, in this way, the excessive thirst of animals to which he had administered poison; and which were incapable of drinking, owing to the œsophagus having been tied. He found, also, in his experiments, that the blood of animals was more and more deprived of its watery portions, as the abstinence from liquids was more prolonged.

Like all other internal sensations, that of thirst arises from a modification of the nerves of the organ, which is inappreciable: hence all the hypotheses, that have been proposed, to account for its cause, have been mere phantasies undeserving of enumeration.

2. The *prehension of liquids* differs somewhat from that of solids. The fluid may be simply poured into the mouth, when it enters by its own gravity; or a vacuum may be formed in the cavity of the mouth, and the pressure of the atmosphere may force it in. When we *drink* from a vessel, the mouth is applied to the surface of the fluid; the chest is then dilated, so as to diminish the pressure of the atmosphere on the portion of the surface of the liquid, intercepted by the lips; and the atmospheric pressure on the surface of the fluid in the vessel forces it into the mouth, to replace the air, which has been removed from the mouth by the dilatation of the thorax.

In *sucking*, the mouth may be compared to an ordinary syringe; the nozzle of which is represented by the lips; the body by the cheeks, palate, &c. and the piston by the tongue. To put this in action, the lips are accurately adjusted around the body, from which the liquid has to be extracted. The tongue is likewise applied, but it soon contracts, and is carried backwards; so that an approach to a vacuum is formed between its upper surface and the palate. The fluid,—now, no longer compressed equally by the atmosphere,—is deplaced, and enters the mouth.

As neither mastication nor insalivation is required in the case of liquids, they do not remain long in the mouth, unless their temperature is too elevated to admit of their being passed down into the stomach immediately, or they be of such a luscious character, that their prolonged application to the organ of taste affords pleasure.

The deglutition of liquids is effected by the same mechanism as that of solids; and,—as they yield readily to the slightest pressure,—with less difficulty. Their accumulation in the stomach takes place in much the same manner. They arrive by successive mouthfuls; and, as they collect, the thirst disappears with all its local and general attendants. If, however, the organ be over-distended, a disposition to vomiting is induced.

The changes, which liquids undergo in the stomach, are of different kinds. All acquire the temperature of the viscus, and become mixed with the secretion from its internal surface, as well as from that of the supra-diaphragmatic portion of the digestive tube. Some, however, undergo the operation of chymification; others not. To the latter class belong,—water, weak alcoholic drinks, the vegetable acids, &c. Water experiences the admixture already mentioned; becomes turbid, and gradually disappears, without undergoing any transformation. Part passes into the small intestine; the other is directly absorbed. When any strong alcoholic liquor is taken, the effect is different. Its stimulation causes the stomach to contract, and augments the secretion from the mucous membrane; whilst, at the same time, it coagulates all the albuminous and mucous portions; mixes with the watery part of the mucous and salivary fluids, and rapidly disappears by absorption; hence, the speedy supervention of inebriety, or death after a large quantity of alcohol has been taken into the stomach. The substances, that have been coagulated by the action of the alcohol, are afterwards digested like solid food. We can thus understand the good effects of a small quantity of alcohol, taken after a substance difficult of digestion,—a custom which has existed from high antiquity and has physiology in its favour. It is, in such cases,—to use the language of the eccentric Kitchener,—a good "*peristaltic persuader.*"

Of the liquids, which are capable of being converted into chyme or chyle, some are so altogether; others in part only. Oil remains longer in the stomach than any other liquid, experiences little change there, but is probably altogether converted into chyle. Milk, as is well known, coagulates in the stomach, soon after it is swallowed, after which the clot is digested, and the whey absorbed. Yet the existence of coagula, in the stomach, is constantly regarded, by the unprofessional, as a pathological condition! Where the liquid, aqueous or spirituous, holds in suspension the immediate principles of animals or vegetables, as gelatine, albumen, osmazome, sugar, gum, fecula, colouring matter, &c., a separation occurs, in the stomach, between the water, or alcohol and the substances combined with them. The latter remain in the stomach and undergo chymification; whilst the aqueous or spirituous portions are absorbed. The salts, united with these fluids, are taken up along with them. In soup, for example, the water and the salts are absorbed; and the gelatine, albumen, fat and osmazome digested.

Red wine, according to Magendie, first becomes turbid by admixture with the juices, formed in, or carried into, the stomach: the albumen of these fluids speedily undergoes coagulation, and becomes flocculent; and, subsequently, its colouring matter, entangled, perhaps, with the mucus and albumen, is deposited on the mucous membrane of the stomach. The aqueous, and alcoholic portions soon disappear.

Liquids reach the small intestine in two forms;—in the state of chyme; and in their unaltered condition. In the former case, they proceed like the chyme obtained from solid food. In the latter case, they undergo no essential change; being simply united with the fluids poured into the small intestine,—the mucous secretions, the bile, and the pancreatic juice. Their absorption goes on as they proceed: so that very little, if any, attains the large intestine.

The mode, in which liquids are expelled, is the same as in the case of the solid excrements.

OF ERUCTATION, REGURGITATION, AND RUMINATION.

Although the contraction of the œsophagus generally prevents the return of matters from the stomach; occasionally this occurs, giving rise to *eructation*, or *regurgitation*, or *vomiting*.

1. *Eructation* or *belching* is the escape of gas from the stomach. If air exist in that organ, it is necessarily situated, as we have seen, near the cardiac orifice. When the aperture relaxes, it passes in, and, unless forced back by the contraction of the œsophagus, speedily reaches the pharynx, causing the edges to vibrate; and hence the sound by which it is accompanied.

2. *Regurgitation.*—If, instead of air, liquid or solid food ascends from the stomach into the mouth, the action is called *regurgitation.* Of this we have an instance in the puking of the infant at the breast; and in the adult, when the stomach is surcharged. Occasionally, too, it occurs when the stomach is empty; in the morning, for example, when it is frequently preceded by eructation, by which the air, contained in the organ, is got rid of.

The mode, in which it takes place, is analogous to that of eructation. The substances, contained in the stomach become accidentally engaged in the cardiac orifice, during the open state of the orifice and the relaxation of the lower part of the œsophagus; owing to the direct pressure of the stomach on its contents, and the abdominal muscles contracting and compressing that viscus. When the food has once passed into the œsophagus, the latter contracts upon it, but inversely, or from below to above. In this way the food ascends into the pharynx, and ultimately into the mouth.

Generally, regurgitation takes place in an involuntary manner; but there are some who are capable of effecting it at will; and can thus discharge the contents of their stomach at pleasure. To accomplish this,—a deep inspiration is taken, by which the diaphragm is forcibly depressed upon the stomach; the abdominal muscles are then contracted, so as to compress the organ; and this effect is occasionally aided by pressing strongly with the hands on the epigastric region. When these efforts are simultaneous with the relaxation of the lower third of the œsophagus, the alimentary matters pass into the œsophagus. This voluntary regurgitation seems to be what is called *vomiting at pleasure.*

3. *Rumination.*—Some individuals have taken advantage of this power to chew the food over again; and subject it to a second deglutition. The function of *rumination* is peculiar to certain animals. Yet man has, in this way occasionally possessed it. Peyer has given numerous examples in his *Merycologia;* and Percy and Laurent, in the article *Merycisme* of the *Dictionnaire des Sciences Médicales.*

The wife of a *frotteur* or rubber of the floors, in the establishment of the then Duke of Orleans,—now king Louis Philip,—could bring up a glassful of water into her mouth immediately after she had swallowed it. Dr. Copland—who published the last editions of the English translation of Richerand's physiology—appears to have seen more than one instance of human rumination, and he describes it as an affection rather to be courted than shunned, so far as regards the feelings of the individual. Under usual circumstances, according to him, rumination commences from a quarter, to an hour and a half, after a meal. The process is never accompanied with the smallest degree of nausea, or with any pain or disagreeable sensation. The returned alimentary bolus is attended with no unpleasant flavour; is in no degree acidulous[?]; is equally agreeable; and is masticated with additional pleasure, and with much greater deliberation than when first taken. The whole of the food swallowed at a meal, is not returned, in order to undergo the process; but chiefly the part that has been insufficiently masticated. The more fluid portions are sometimes, however, returned along with the more solid: but when the stomach is distended by a copious meal, the fluid contents are frequently returned, and subjected to the process.

4. *Vomiting.*—The inverted action of the stomach, preceded, as it always is, by manifest local and general disturbance, cannot properly be regarded as within the domain of physiology. It is, however, so nearly allied to the phenomena we have just considered, and has engaged so much of the time of the physiologist, as well as of the pathologist, that it requires mention here.

From regurgitation it differs essentially,—in the sensation that precedes, the retching that accompanies, and the fatigue, that generally succeeds it; in short, whilst in regurgitation no indisposition may be felt, in vomiting this is always present, more or less.

The *sensation of the desire to vomit* is termed *nausea.* It is an indescribable feeling of general indisposition; sometimes accompanied with a sensation of circumgyration, either in the head or epigastric region; trembling of the lower lip, and copious flow of the saliva: along with these signs, there is manifest diminution of the powers of the vascular and nervous systems: hence the utility of nauseating remedies when these systems are inordinately excited.

The causes, which produce nausea, show that it may be either an external or internal sensation. Those, that occasion it directly or externally, are certain emetic substances; too great distention of the stomach, or the presence of food in it which disagrees by its quality; morbid secretions; the reflux of the bile from the duodenum, &c. All these are so many immediate irritants, which develope the sensation, as the external sensations in general are developed. In other cases, however, the cause acts at a distance. Between the stomach and various organs of the body, such extensive sympathetic relations exist, that if one of these be long and painfully affected, the stomach sooner or later sympathizes, and nausea, or vomiting, or both are produced. In many instances, indeed, the cause is much more remote than this; the sight of a disgusting object, an offensive smell, or nauseous taste will as certainly produce the sensation as any of the more direct agents.

To this class of causes belongs the nausea, produced by riding in a carriage with the back to the horses, by swinging, and particularly by sailing on the ocean.

How the motion, which obviously excites the nausea in these cases, acts, has been the subject of many speculations, especially as regards sea-sickness. Darwin refers it to an association with some affection of the organs of vision, which, in the first instance, produces vertigo; and Bourru, in his French translation of the work of Gilchrist,—"on the utility of sea voyages in the cure of different diseases,"—ascribes it to irritation of the optic nerves, caused by the impossibility of fixing the eyes on objects soon after embarking. The objection to these views is, that the sickness ought to be prevented by simply covering the eyes, and that the blind ought to be exempt from it, which is not the case. Wollaston attempted to explain it, by some change in the distribution of the blood; the descending motion of the vessel causing an accumulation of blood in the brain, as it causes the mercury to rise in the tube of a barometer. But this explanation is too physical. The mercury, in an unyielding tube, is readily influenced by the motions of the vessel; but the blood in the living animal is situated far otherwise. It is under the influence of a vital force, which interferes greatly with the action of causes, that are purely physical. Were it otherwise we should be liable to alarming accidents, whenever the body is exposed to the slightest concussion.

The generality of pathologists consider, that the first effect is upon the brain, and that the sensation is produced consecutively, through the influence of that organ on the stomach; and it is difficult not to accord with this view; whilst we admit, that the precise manner, in which this is effected, is entirely beyond our cognizance, like every other phenomenon, indeed, of the nervous system. In the case of nausea, produced by the sight of a disgusting object, we have this catenation of actions somewhat more clearly evidenced.

The impression must, manifestly, in this case, be conveyed to the brain by the optic nerves, and from that organ the sensation must emanate. It is probable, too, that when emetics are injected into the veins, the first effect takes place on the brain, and the stomach is affected secondarily.

When the state of nausea, however produced, continues for any length of time, it is usually followed by vomiting. The rejected matters are generally from the stomach, but if the retching or violent contractile efforts of the muscles concerned be long continued, the contents of the small intestine also form part; hence, we account for the universality of the presence of bile in the rejected matters after an emetic has been taken, which is therefore no evidence, in the generality of cases, of the persons being, what is termed, *bilious.* The contents of the small intestine are returned into the stomach by an antiperistaltic action. The longitudinal fibres take their fixed point below, and contract from above downwards; so that the chymous mass is forced towards the upper part of the canal, whilst the circular fibres contract from below to above.

In cases of *colica ileus*, or the *iliac passion*, the inverted action extends through the whole intestinal canal; so that fæcal matters, and even substances injected into the rectum, will force the ileo-cæcal valve, and be discharged by the mouth.

Of old, it was universally maintained, that vomiting is caused by the sudden and convulsive inverted contraction of the stomach; and they, who admitted that the diaphragm and abdominal muscles take part in the action, looked upon them simply as accessories. Francis Bayle, Professor in the University of Toulouse, in 1681, appears to have been the first, who suggested, that the stomach is nearly passive in the act; and that vomiting is caused, almost exclusively, by the pressure, exerted upon that organ, by the diaphragm and abdominal muscles. His reason for this belief was founded on the fact, that, having introduced his finger into the abdomen of a living animal, whilst it was vomiting, he could not perceive any contraction of the stomach. In 1686, Chirac repeated the experiment with similar results; after which, the views of Bayle were embraced by many of the most eminent physiologists and pathologists,—by Senac, Van Swieten, Schulze, Schwartz, and at a later period, by the celebrated John Hunter, who maintained, that the contraction of the muscular fibres of the stomach is not essential to the act of vomiting.

Many distinguished physiologists, however, ranged themselves on the opposite side. Littre maintained, that the stomach is provided with considerable muscular bands, capable of powerful contraction; and that vomiting is often caused without the participation of the abdominal muscles, as in the case of ruminant animals. We have seen, however, that the rumination of animals more resembles regurgitation. Lieutaud argued, that, according to Bayle's theory, vomiting ought to be a voluntary phenomenon; that the stomach is too deeply-seated to be compressed by the neighbouring muscles, so as to empty it of its contents; and he details the singular case of a female, who, whilst labouring under an affection, for which emetics seemed to be required, resisted the action of the most powerful substances of that nature. After her death, Lieutaud, feeling desirous to detect the cause of this resistance, had the body opened in his presence, when the stomach was found enormously distended, but its structure unaffected. He, consequently, inferred, that the stomach had become paralyzed from over-distention, and that the effect produced was similar to that, so often met with in the bladder, when it has been long and largely distended. This case seemed to prove to him, that the stomach is most concerned in the act of vomiting, as the abdominal muscles and diaphragm appeared healthy, and no obstacle existed to their contraction. It is singular, however, that the emetic substances should not have excited the contractions of the diaphragm and abdominal muscles; especially as there is reason for believing, that many of them at least, under ordinary circumstances, are taken into the blood, and affect the brain first, and through its agency the muscles, concerned in the act of vomiting. The case seems to have been one of unusual resistance to the ordinary effects of nauseating substances, and cannot be looked upon as either favourable or unfavourable to the views of Bayle. We find, that vomiting does not follow the exhibition of the largest doses of the most powerful emetics, if the energy of the nervous system be suspended by the inordinate use of narcotics, or by violent injuries of the head.

Lieutaud farther remarks, that, according to his theory, vomiting occurs at the time of inspiration; but this cannot be, as the lower part of the œsophagus is, at this time contracted, and if the vomited matters could reach the pharynx, they would pass into the larynx.

Dr. Marshall Hall has attempted and successfully, to show, that the larynx is closed during vomiting; and has concluded, that the act is a modification of expiration, or that the muscles of expiration, by a sudden and violent contraction, press upon the contents of the stomach, and project them through the œsophagus.

Haller maintained the ancient doctrine, that the stomach, alone, is competent to the operation. His views were chiefly founded on his theory of irritability, which compelled him to admit contraction, wherever there are muscular fibres; and on certain experiments of Wepper, who asserted, that when he produced vomiting by metallic substances, he observed the stomach contract.

The *Académie des Sciences* of Paris, unsatisfied with the results of previous observations, appointed Duverney to examine into the question, experimentally and otherwise; who, although he did not adopt the whole theory of Chirac, confirmed the accuracy of the facts on which it rested. He demonstrated that the stomach is but little concerned in the act; and that it is chiefly dependent upon the contraction of the diaphragm and abdominal muscles, which close the stomach as in a press, so that its contents are compelled to return by the œsophagus.

On the other hand, in 1771, Portal, in his lectures at the college of France, endeavoured to show, that the stomach is the great agent in vomiting. He administered to two dogs, arsenic, and nux vomica, which produced vomiting. The abdomen was immediately opened; and, according to Portal, the contractile movements of the stomach could be both seen and felt; and it was noticed, that instead of the vomiting being dependent upon the pressure of the diaphragm upon the stomach, it occurred at the time of expiration; and was arrested during inspiration, because the depressed diaphragm then closes the inferior extremity of the œsophagus;—with such strength, indeed, that the contents cannot be forced into the œsophagus, when we press upon the organ, with both hands. The views of Portal were confirmed by the experiments of Haighton. He opened several animals during the efforts of vomiting; and he states, that he distinctly saw the contractions of the stomach.

In more recent times, the physiological world has been again agitated with this question.

In 1813, M. Magendie presented to the French Institute the result of a series of experiments on dogs and cats,—animals, which vomit with facility.

Six grains of tartarized antimony were given to a dog; and, when he became affected with nausea, the linea alba was divided, and the finger introduced into the abdomen, to discover the state of the stomach. No contraction was felt; the organ appeared simply pressed upon by the liver and intestines, which the contracted diaphragm and abdominal muscles crowded upon it. Nor was any contraction perceptible to the eye; on the contrary, the stomach appeared full of air, and three times its usual size. This air manifestly came from the œsophagus, as a ligature, applied round the cardia, completely prevented its appearance. From this experiment Magendie inferred, that the stomach is passive in vomiting.

A solution of four grains of emetic tartar in two ounces of water was injected into the veins of a dog; and, as soon as nausea took place, an incision was made into the abdomen, and the stomach drawn out of the cavity. Although the retching continued, the viscus remained immovable, and the efforts were vain. If, on the other hand, the anterior and posterior surfaces of the stomach were pressed upon by the hands, vomiting occurred, even when no emetic tartar was administered; the pressure provoking the contraction of the diaphragm and abdominal muscles, and thus evidencing the close sympathetic connexion, which exists between these acts. A slight pull at the œsophagus was attended with a similar result.

In another dog, the abdomen was opened; the vessels of the stomach tied and the viscus extirpated. A solution of two grains of tartar emetic in an ounce and a half of water was then injected into the veins of the animal; when nausea and fruitless efforts to vomit supervened. The injection was repeated six times: and always with the same results.

In another dog, the stomach was extirpated; and a hog's bladder fitted to the œsophagus in its stead, containing a pint of water which distended but did not fill it. The whole was put into the abdomen; the parietes of which were closed by suture. A solution of emetic tartar was now injected into the jugular vein of the animal: nausea—and, afterwards, vomiting—supervened, and the fluid was forced from the bladder.

On another dog, the phrenic nerves were divided; by which three-fourths of the diaphragm were paralyzed; the dorsal pairs being the only nerves of motion remaining untouched. When emetic tartar was injected into the veins of this animal, but slight vomiting occurred; and this ceased, when the abdomen was opened and the stomach forcibly pressed upon.

In another dog, the abdominal muscles were detached from the sides and linea alba; the only part of the parietes remaining being the peritoneum. A solution of emetic tartar was now injected into the veins: nausea and vomiting supervened; and, through the peritoneum, the stomach was observed to remain immovable; whilst the diaphragm pressed down the viscera so strongly against the peritoneum, that it gave way, and the linea alba alone resisted.

In a final experiment, Magendie combined the two last. He cut the phrenic nerves to paralyze the diaphragm; and removed the abdominal muscles. Vomiting was no longer excited.

From these different results, he decided, that vomiting takes place independently of the stomach; and on the other hand, that it cannot occur without the diaphragm and abdominal muscles; and he concluded, that the stomach is almost passive in the act; that the diaphragm and abdominal muscles, especially the first, are the principal agents; that air is constantly swallowed at the time of vomiting, to give the stomach the bulk which is necessary, in order that it may be compressed by those muscles; and lastly, that the diaphragm and abdominal muscles are largely concerned in vomiting, as is indicated by their evident and powerful contractions during the act, and by the fatigue which is felt in them afterwards. Magendie likewise refers, in corroboration of his view, to the cases of scirrhous pylorus, in which there is constant vomiting, although a part of the tissue of the stomach has become cartilaginous, and, consequently, incapable of contraction.

Clear as the results, obtained by this dexterous experimenter, seem to be, they have been controverted; and attempted to be overthrown by similar experiments.

Soon after the appearance of Magendie's memoir, M. Maingault, laid before the Society of the *Faculté de Médecine* of Paris, a series of experiments, from which he decuced very different results. In all, vomiting was produced without the aid of the diaphragm and abdominal muscles. The vomiting was excited, in these experiments, by pinching a portion of the intestine, which acts more speedily than the injection of substances into the veins.

The abdomen of a dog was opened, and a ligature passed around a portion of intestine. The whole was then returned into the abdomen; the wound closed by suture; and vomiting took place. All the abdominal muscles were next extirpated; the skin, alone, forming the paries of the cavity. This was brought together, and the vomiting continued.

On another dog, three-quarters of the diaphragm were paralyzed by the section of the phrenic nerves. The abdomen was now opened, and a ligature placed round a portion of intestine. Vomiting occurred.

Lastly;—these two experiments were united in one. The abdominal muscles were cut crucially, and removed; whilst the phrenic nerves were divided; and the muscle even cut away from its fleshy portion towards its tendinous centre; leaving only, under the sternum, a portion as broad as the finger. At the same time, the integuments were not brought together; yet vomiting continued. As these results were obtained on numerous repetitions of the experiment, Maingault conceived himself justified, in deducing inferences, the very opposite to those of Magendie, namely,—that the contraction of the diaphragm and abdominal muscles is only accessory to the act of vomiting; and that the action of the stomach is its principal cause; that the latter is not a convulsive contraction, which immediately strikes the eyes; but a slow, antiperistaltic action; and that the only convulsive movement is the contraction of the œsophagus, which drags the stomach upwards.

Maingault, besides, adduces various considerations in favour of his deductions. If the stomach, he asks, be passive, why does it possess nerves, vessels, and muscular fibres? Why is vomiting more energetic, when the stomach is pinched nearer to its pyloric orifice? Why are the rugæ of the mucous membrane of the stomach, during vomiting, directed in a divergent manner from the cardiac and pyloric orifices towards the middle portion of the organ? If the diaphragm does all, in the act of vomiting, why do we not vomit whenever the diaphragm contracts forcibly? Why does not the diaphragm produce the discharge of urine in paralysis of the bladder? Why is vomiting not a voluntary phenomenon? and, lastly, how is it that vomiting occurs in birds, which have no diaphragm?

The minds of physiologists were of course distracted by these contradictory results. Richerand embraced the views of Magendie; and affirmed, that he had never observed contraction of the stomach; and that it seemed to him the least contractile of any part of the intestinal canal. With regard to the experiments of Maingault, he considered, that the stomach had not been wholly separated from the surrounding muscles; that the action of the pillars of the diaphragm, and the spasmodic constriction of the hypochondres are sufficient to compress the viscus; that besides, nothing is more difficult to effect than the section of the phrenic nerves below their last root; and, moreover, such section does not entirely paralyze the diaphragm, as the muscle still receives twigs from the intercostal nerves and the great sympathetic; that the cardia, being more expanded than the pylorus, the passage of substances through it is rendered easy; and that it is incorrect to say, that the cardiac orifice, during inspiration, is closed between the pillars of the diaphragm. Again, to object that, according to the theory of Magendie, vomiting ought to be a voluntary phenomenon, is a feeble argument; for it is admitted, that the muscles, which, at the time, compress the stomach, act convulsively. If the diaphragm, in paralysis of the bladder, cannot effect the excretion of the urine, it is because that reservoir is not favourably situated, as regards the muscle: and, lastly, the arguments deduced from birds, which are capable of vomiting, although they have no diaphragm, is also insufficient; for it is not absolutely necessary that it should be a diaphragm, but any muscle, which can compress the stomach.

When the Memoir of Maingault was presented to the society of the *Faculté de Médecine*, M. Legallois and Professor Béclard were named reporters. The experiments were repeated before them by M. Maingault, but, instead of appearing contradictory to those of Magendie, these gentlemen declared that they were not sufficiently multiplied, or sufficiently various, to lead to any positive conclusion. MM. Legallois and Béclard, subsequently, repeated those experiments; varied them, and instituted others; from which they deduced corollaries, entirely conformable to those of Magendie; and lastly, Bégin boldly affirms, "without fear of being contradicted by facts, that there is no direct or authentic experiment, which demonstrates the activity of the stomach during vomiting:"—and he adds, "I have repeated the greater part of the experiments of Magendie; he has performed all, in presence of a great number of spectators, of whom I was one; and I can say, with the commissioners of the *Académie des Sciences*, that I have seen, examined, touched, and my conviction is full and entire." Still, there are many eminent physiologists, who hold on to the idea, that the stomach is the main agent in vomiting; and amongst these is Broussais. He manifestly, however, mixes up the phenomena of regurgitation with those of vomiting: which, we have endeavoured to show, are distinct.

On the whole, we are perhaps justified in concluding, that the ancient doctrine, regarding vomiting, is full of error, and ought to be discarded;—that the stomach is, of all the organs concerned, the one whose action is the least energetic and necessary,—that the pressure, exerted on the parietes of the stomach by the diaphragm and abdominal muscles, is the most powerful cause,—and that the more or less complete paralysis of the diaphragm or the destruction of the abdominal muscles renders vomiting much more feeble and slow in manifesting itself.

The order of the phenomena seems to be as follows:—The brain is affected directly or indirectly by the cause exciting vomiting; by the brain, the diaphragm and abdominal muscles are thrown into appropriate contraction, and press upon the stomach; this organ probably contracts from the pylorus towards the cardia; and, by the combination of efforts, the contents are propelled into the œsophagus, and out of the mouth. These efforts are repeated several times in succession, and then cease,—at times, to reappear.

Whilst the rejected matters pass through the pharynx and mouth, the glottis closes; the velum palati rises and becomes horizontal, as in deglutition; but owing to the convulsive action of the parts, these apertures are less accurately closed, and more or less of the vomited matter passes into the larynx or nasal fossæ. On account of the suspension of respiration impeding the return of blood from the upper parts of the body, and partly owing to the force, with which the blood is propelled by the arteries, the face is flushed or livid, the perspiration flows in abundance, and the secretion of tears is largely augmented.

END OF VOL. I.

- PAGES 245 - 246 torn in middle
- PAGE 262 - broke when I turned the page

SOME BRITTLE PAGES